An Introduction to the Diversity of Approaches to Vulnerability Research and Assessment: Common Features and Lessons Learned

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1 The vulnerability trap

In the last ten years, the study of vulnerability has mushroomed. The Intergovernmental Panel on Climate Change (IPCC), for example, shifted the focus of their second working group from one studying climate change impacts, to one studying climate change vulnerability, in their 2001 report (McCarthy et al., 2001). Recently, the term vulnerability has increasingly been used in environmental sciences, ecology, resource management and development, in particularly concerning phenomena of global change and the Earth system. In this book we focus on vulnerability to global environmental change. There have been a growing number of local and regional assessments of vulnerability, particularly to climate change, or a combination of climate change and other factors.

Probably the most important cause of this attention to vulnerability is the recognition that global changes of important magnitude, in particular climate change, are already taking place, and that the nature and magnitude of potential impacts, according to modeling exercises, could be dramatic (Schröter et al., 2005a). Since the 1980s, scientists and policy-makers have debated how much effort should be spent to stop or limit climate change, and what policy instruments would be the best tool to use. But as these debates have been going on, it has increasingly been recognized that a certain amount of climate change has already occurred, and that no matter what policies come into place, an ever-greater amount of climate change will occur in the future (IPCC, 2001). In the last hundred years, global mean temperatures have risen approximately 0.6°C, with evidence of corresponding changes in precipitation, sea level rise, and occurrence of extreme events (Folland et al., 2001). But these have been simply the transient responses to the change in greenhouse gas concentrations that have already occurred, meaning that the planet has not yet come into equilibrium. Should we stop increasing the atmospheric concentration of CO_2 and other greenhouse gasses now, one recent modeling study suggests, we could still experience at least another 0.5°C or warming, potentially much more, and a degree of sea level rise several times what we have already experienced (Meehl et al., 2005). In the more likely case that society reduces its CO_2 emissions neither completely nor immediately, these changes will be even greater. On top of this, there is the threat that important thresholds could be passed, leading to irreversible changes in the basic states of several global system, such as the North Atlantic thermohaline circulation (Broeker, 1997), the Amazon basin rainfall regime (Laurance and Williamson, 2001), or the Asian monsoon (Gupta et al., 2003). The apparent inevitability of future climate change of a magnitude greater than society has ever experienced makes it increasingly important to anticipate and adapt. For the first time in human history, policy-makers are now trying to manage, at a global scale, the long-term consequences of gradual change.

Science plays a vital function not only in suggesting but also in justifying policy-decisions. Ezrahi (1990) argues that modern systems of governance rely on science for their very legitimacy, much as past monarchies relied on claims of divine right. Policy-makers need to show that their decisions are supported by sound scientific theory. In recent decades, there have been several cases where the public has not only called into question the validity of the science on

which policy-makers relied, but also succeeded in revealing its shortcomings (Wynne, 1996). The result, many scholars suggest, is a public that is rightfully skeptical of the claims that scientists make, and less than willing to trust them (Freudenberg, 1996; Hoffman-Reim and Wynne, 2002). If scientists cannot demonstrate the validity of their knowledge to the people who will be affected, they will not only be ignored (Michael, 1996), but their future reputation will be harmed (Glantz, 2000). Scientists involved in the policy-making process, whether there willingly or not, now carry the burden of proof for the knowledge claims they make. Those who fail to do so risk harming not only their own credibility, but also the credibility of their colleagues.

The onus is especially difficult to bear in the realm of vulnerability. Scientists conducting vulnerability assessment gather a great deal of important and reliable information about the various factors that likely give rise to vulnerability, such as the direction and magnitude of future climate change, the existing stresses on the human environment system, and economic indicators that may increase or lessen adaptive capacity. None of these factors is a measure of vulnerability itself, but rather is an indicator that, when combined with other indicators according to one or more theoretical models, contributes to an overall picture. However, because of the lack of precedent for the current combination of global environmental changes, scientists need to wait twenty, fifty or one hundred years to validate those very theoretical models. Indeed there are now many competing models, rooted in different scientific traditions, each suggesting that it is a slightly different combination of factors that lead to increased vulnerability. By calling on scientists to assess vulnerability, and to use a theoretical model to aggregate their data into a form that is useful, policy-makers are setting an unwitting trap. Scientists are drawn to assess vulnerability, either out of a desire to save the world or else out of simple vanity, and given the importance of their work, this lands them squarely in the public limelight. Yet in this process, they can easily make statements that they are unable to support with credible theory, or to defend against competing claims. Having their advice ignored is not the worst that can happen.

The purpose of this book is to suggest how scientists conducting vulnerability assessment can avoid falling into this trap, and how policy-makers and stakeholders can avoid setting it in the first place. The thesis of this book is that, at least for now, the study of vulnerability to global environmental change can and should fall within the domain of policy analysis—engineering practical solutions to pressing problems—rather than within the much broader discourse of social and systems science. Past vulnerability assessments have shown that while scientists can offer an abundance of valuable information on vulnerability to stakeholders and policy-makers, no single indicator or single theory of vulnerability will be helpful or credible for the purpose of understanding and lessening the vulnerability of a specific place or system (Schröter et al., 2005b). Instead we must engage in a open dialogue relying on the best available science and inviting the participation of all relevant stakeholders to come to adaptation strategies and solutions that should be monitored and revised continuously as the future, and our effect on it, unfolds.

In this introductory chapter, we will lay out our argument, first by discussing the basis for theory on vulnerability, second by describing the various reasons to assess vulnerability, and third by describing the ways to conduct vulnerability assessment such that it is useful. Finally, we introduce the remaining chapters of the book, each of which tells a different story about vulnerability and vulnerability assessment, told from a different perspective, and each of which suggests that the thesis of this book is correct

2 Vulnerability research

Several review articles document the development of vulnerability within the social and environmental sciences. We briefly summarize this history here, in order to set the stage for out discussions of purpose of vulnerability research. Global environmental change vulnerability assessments are rooted in three traditions of research: risk/hazard research, food security studies, and most recently, climate impact assessment. The first of these grew out of efforts to identify the potential effects of acute pressures on a system. The focus is on vulnerability to a single cause of harm, and how other features of a system could exacerbate or mitigate that harm (Cutter 1996, Jaeger et al. 2001, Cutter et al. 2003, Porto and de Freitas 2003). For example, an earthquake might damage a human settlement. The extent and form of the damage can depend on physical features of the system, such as the construction of buildings. How quickly the system can recover from the damage, in turn, depends on institutions: emergency teams take care of the injured and the dead; and insurance mechanisms facilitate rapid rebuilding. The second of these is centered not on a single cause, but a single effect, namely hunger and famine (Ribot et al., 1996). While it was initially attractive to lay the blame for hunger on a particular cause, such as a famine, the theory of economic entitlements, propounded by Amartya Sen, convincingly demonstrated that people's physical or latent resources play at least as great a role (Sen, 1981). In researching the vulnerability to a single outcome (rather than a source of harm), these researchers attempt to examine the interactions of multiple stresses, often building over time.

The third tradition, climate impact assessment, initially focused on determining the marginal damages associated with the human choice to place additional greenhouse gasses into the atmosphere. Like hazard assessment, this strand of vulnerability assessment concerns itself primarily with a single driver of harm. However, just as vulnerability to food security increases slowly over time as entitlements erode, so too will climate impacts accumulate gradually over long time scales. It thus becomes necessary, in assessing climate change impacts, to consider other exacerbating causes or adaptations that may develop over the same time span, and which will either exacerbate or lessen the harm. For this reason, the field of climate change impact assessment has evolved into that of global environmental change vulnerability assessment. Since the publication of its First and Second Assessment Report (IPCC, 1990; IPCC, 1995), the Intergovernmental Panel on Climate Change (IPCC) has contributed considerably to the increased usage of the vulnerability concept. In its Third Assessment Report the IPCC has moved from a climate impact oriented view to a broader, more integrated and less climate focused perspective on vulnerability (IPCC, 2001; McCarthy et al., 2001). The concept of global environmental change vulnerability embraces multiple causes and multiple effects of global change for a single but highly complex concern: human well-being (Kelly and Adger, 2000; Luers et al., 2003; Metzger and Schröter, 2005 (in review); Schröter et al., 2005a).

2.1 Development of theory

It is worth considering how scientists working in each of these strands conduct their research to build theory. The critical feature of vulnerability, whether it is vulnerability to a hazard, vulnerability to famine, or global change vulnerability, is that it cannot be observed or measured directly, but rather must be deduced. What do we mean? Vulnerability is not a statement about how a system functions in the present, but rather about how it is likely to function in the future, namely that it will not function as well in the future as it does today, causing additional numbers of people to suffer The future, of course, cannot be observed, at least not yet. To surmise that a system is vulnerable, one has to combine projections of what events the future will bring with a theory of how these events will make the system under study worse off. For many simple

systems, this is trivially easy. A pumpkin that is thrown from the top of the Eiffel Tower is obviously in a highly vulnerable state (as are those walking under it!), since it is fairly easy to predict that it will crash against the ground, rather hard. Most human environment systems are far more complex, such that reasonable minds can differ as to whether they are headed for a crash, or will discover an appropriate parachute to ensure a soft landing. For example, consider the interaction of climate change and deforestation in the Amazon, factors that may lead to irreversible transformation (Laurance and Williamson, 2001). Not only did it take decades to recognize that such an outcome was possible, but how the future will unfold is still subject to a great amount of uncertainty. Ultimately, whether a system was vulnerable today to a future event can only be known for sure once that future event has come and gone. But by then, of course, any assessment of today's system vulnerability is too late. One response to this is to employ the precautionary principle in areas where irreversibility may occur. Another is to engage in developing robust theory about the relationships between current system state variables and the likelihood of future collapse.

In the areas of hazards and famines, theory has been built on the analysis of past crises. For example, Sen grounded his theory of entitlements in an analysis of the past famines, such as that occurring in Bengal from 1941-43 (Sen, 1981). Some measure of historical analysis is also appropriate to study global change vulnerability, as several authors (Fraser, chapter 2, and Schröter, chapter 7) demonstrate in this volume. Increasingly, archeologists are able to connect the decline and collapse of ancient societies to changes in their natural environments.

For example, consider the story of the Norse settlers in Greenland, (Diamond, 2004). These people depended on a limited supply of land, lying along coastal inlets, to sustain their farming livelihoods. Unfortunately, they degraded that land through many of their traditional practices, which in retrospect appear unsustainable. For example, they used turf, valuable as farmland and in far more limited supply in Greenland than it had been in Norway, as a building material for their houses. This in turn increased the pressure they placed on the remaining land, and their sensitivity to changes that might make that land less productive. It was just a matter of time before they overgrazed that land, caused erosion, and then entered a cycle of decline, as they depended on an ever-shrinking area to supply them with their livelihoods. This was made worse by a gradual change in climate, over which they had no control. They had arrived in Greenland during a relatively warm period, but over the coming decades, the winters became longer and colder, and the summers less life-sustaining. Eventually, as a combination of local environmental degradation and regional climate change made a farming lifestyle impractical on Greenland, they turned to eating fish and seals. By analyzing the elemental isotopes in their bones, it is possible to identify a shift in their foodstuff from terrestrial to marine. But here another issue becomes important. Unlike the nearby Inuit people, who had long hunted on the sea and been able to survive on Greenland, the Norse did not have these skills or traditions. Moreover, many of their own traditions, including their religious practices and a fundamental lack of respect for the Inuit, left the Norse unwilling or unable to learn from the Inuit. Rather than adapt their ways and copy the Inuit, such as by adopting the kayak and the harpoon as tools, the Norse remained poor at hunting seals. Ultimately, as Diamond chronicles, the Norse settlement on Greenland died completely.

Analyzing such case studies, one sees quite clearly that vulnerability is a consequence of multiple factors. Diamond proposes, for a first order analysis, to look to five factors to understand what made past societies vulnerable to collapse: environmental damage, climate change, hostile neighbors, the loss of friendly trading partners, and the society's responses to its environmental challenges. Furthermore, case studies like that of the Greenland Norse show what can be at stake:

these past cultures did not simply suffer minor declines in their standard of living, a small risk they may have voluntarily taken in exchange for the short-term benefits their unsustainable behaviour probably brought them. Rather, the worst-case scenario eventually occurred, and they all died something that probably seemed as out of the question to them then as our own civilization's demise seems to us today. Other societies, like the Maya in Central America and the inhabitants of Easter Island, did not all die, but their civilization went into an irreversible decline of prosperity. Finally, the case studies also show how hard it can be to predict events that will lead to a society's demise. For example, the Norse were among the best boat-builders in the world, and had launched successful expeditions across the Atlantic, setting up temporary outposts on the North American mainland, hundreds of years before the Spanish, English, and Portuguese were to do the same. Yet part of their downfall in Greenland was their failure to make use of the simple Inuit kayak for hunting seals. They probably had the skill to copy the Inuit design, but Diamond suggests that they refused to do so because they viewed the Inuit as morally inferior. The Norse proved to be remarkably un-adaptive, but it was not because they lacked the capacity.

Case studies such as that of the Norse can contribute to the theory of vulnerability in important ways, but they cannot complete it. We live in a global society where no single group of people need ever be out of contact, for more than a few hours or days, with the rest of civilization Due to the greater linkages between societies than has ever existed in the past, the modern situation is fundamentally more complex than that of the isolated Greenland settlement. Moreover, the current threats are unlike any that have been experienced in the past. If current estimates of climate sensitivity are correct, the magnitude of climate change, all across the globe, will dwarf any that has occurred since the dawn of human civilization. To some extent, theory on the vulnerability of contemporary human environment systems to global change must be built not on observations of past systems that have experienced unprecedented change, but rather extrapolated from studies of societies facing far less significant stress. Exactly how best to extrapolate has been the subject of vigorous academic debate.

2.2 Current debates

Perhaps invisible to the policy-makers who commission vulnerability assessment, there is a vigorous academic debate about exactly how vulnerability should be defined, analyzed, and framed. Some parts of the debate focus on the confusing use of language, while others cut to the heart of what vulnerability actually is.

At the level of language, for example, researchers argue whether we should describe a system as being vulnerable to an external stressor (e.g., an earthquake, or climate change), or an outcome (e.g., famine) (Suarez and Ribot, 2003). Those arguing the former suggest that a focus on a limited number of stressors is essential to link vulnerability assessment to the decisions of real people and government agencies (Dilley and Boudreau, 2001). Those arguing the latter suggest that it is essential to remain open to the multiple interacting sources of harm (Ribot et al., 1996).

At the level of definition, there are debates about what are the features of a system that give rise to vulnerability, what should be the scale of the study, what are the appropriate indicators of vulnerability, and whether indicators are even appropriate. There have been numerous competing frameworks and flowcharts suggesting the pathways by which a system becomes more or less vulnerable (Füssel and Klein, in press; Jones, 2001; Kasperson et al., 1995; Metzger et al., 2005a; Patt et al., 2005a; Turner et al., 2003a). Some have suggested that for information about vulnerability and environmental threats to influence decision-makers, it is vital that it "fit" the temporal and spatial scale at which decisions can be made (Orlove and Tosteson, 1999). Others,

however, suggest that one needs to analyze nested scales (e.g. Stephen and Downing, 2001), both spatial (O'Brien et al., 2004b) and temporal (Schröter et al., 2004). With respect to indicators, there have been numerous propositions, each weighing a different set of features of the system, and based on a slightly different model of vulnerability. The IPCC, for example, proposes the well accepted idea that vulnerability is a function of exposure, sensitivity, and adaptive capacity (McCarthy et al., 2001), although exactly what form that function should take remains vague (Füssel and Klein, in press). Many researchers have proposed quantitative indicators, which then allow mapping to reveal relative levels of vulnerability. Luers et al. (2003) suggest an indicator that takes into account how far a spatial grid cell is from a threshold value of environmental stress. O'Brien et al. (2004a) suggest a very different indicator that highlights the interaction of two quite different stressors. Schröter et al. (2005a) settled on mapping a set of indicators, each corresponding to a different environmental stress; additionally, they essentially gave up on trying to include adaptive capacity within those indicators. Others, however, argue that the very idea of vulnerability indicators is flawed. First, they suggest that few if any decisions will be based on indicators of relative vulnerability, but that the focus of analysis needs to be on how to make each element of the system less vulnerable. Moreover, any indicator will fail to take into account the tremendous heterogeneity of vulnerability even within the smallest of scales (Suarez and Ribot, 2003). Finally, many of the current indicators of vulnerability are deceptive because they fail to convey the unavoidable uncertainty they contain (Patt et al., 2005a).

Perhaps nowhere is the debate stronger than in the issue of adaptive capacity. What is it, what causes it, and when does it express itself? If one measures vulnerability by the loss of life that occurs in the wake of disaster, and adaptive capacity can avoid that loss of life, then financial wealth is a clear and simple indicator of adaptive capacity (Yohe and Tol, 2002). If one measures vulnerability by total damages, and include in the analysis not just wealth but also the factors that are precursors to wealth, then money loses its place of importance compared to transportation infrastructure and other physical system features (Brooks and Adger, 2004). If adaptive capacity includes not just the ability to change, but also the willingness to (something the Greenland Norse apparently lacked), then psychological indicators prove to be far more predictive than economic ones (Grothmann and Patt, 2005; Grothmann and Reusswig, in press). Other studies suggest that it is not simply the agents who do the adapting that matter, but also their relationship to the communicators of the information on which they would act (Patt et al., in review), how organizations that communicate this knowledge are structured (Cash et al., 2003), and in what form they present it (Patt et al., 2005b). Adaptive capacity is an intellectual quagmire. This is not surprising, since adaptive systems change the way they respond to a stimulus over time (Bradbury, 2002). Numerical models of adaptive systems are simple, if they exist, and do not take into account the multitude of actors and factors needed to represent most real world systems.

The current debates about global change vulnerability reflect two important points. First, as we have already shown, there is a paucity of data to guide our study of global change vulnerability. Researchers may suggest alternative models and indicators, and need to rely on a combination of logical argument and an extrapolation of pre-existing models far beyond their boundary conditions in order to support their propositions. Second, and more importantly, research on global change vulnerability is driven more by the needs of policy-makers than by curiosity about unanswered riddles within the scientific community. Many vulnerability studies, such as those that Diamond so well describes, are fueled by the desire to understand why past societies have collapsed, and here they stand on the firmest ground. But more often, they are fueled by the legitimate desire of a broad range of policy-makers and concerned scientists to avoid imminent harm. In this case, not only are the factors that may lead to harm very heterogeneous, but so too are the types of harm that concern them. Some may legitimately by worried about the entire

collapse of their society. Others fear the loss of human life and infrastructure. Still others care about the disruption of historical patterns of social and environmental functioning. The debates around how exactly to quantify or even describe vulnerability represent an attempt to pin the word down to a particular technical and legalistic definition. Yet as long as the word "vulnerability" is spoken by those feeling exposed and fearing loss, it will continue to mean very different things to very different people, and any debates about how exactly to define it will not cease. Instead of hiding our perceptions and values in discussions about definitions, it makes sense to communicate openly what we value and why as part of any discourse on vulnerability. Some would argue that this then is the very point of departure of vulnerability assessment from a purely scientific exercise. Others feel that the distinction between facts and values is less clear, and that values should be a matter of open discourse as much as facts (Putnam, 2002).

3 Vulnerability assessment

The resolution to these debates lies not in working harder to develop a better theory of vulnerability, but in better recognizing that work on vulnerability is driven primarily by policy needs, rather than scientific curiosity. Many of the disputes about global change controversy evaporate when one sees it as a proper subject not of scientific research, but of scientific assessment.

Scientific research and scientific assessment are different beasts. The goal of scientific *research* is primarily to develop general theory, which can be applied in places and contexts other from that where the research took place. Hence, social scientists interested in the causes of vulnerability can study the collapse of ancient societies, and learn something that may be useful to our own society. The selection of case studies, of the temporal and spatial scale of analysis, and indeed of the methods for collecting and analyzing data, needs to be made in order to yield results that are of as general validity as possible. By definition the goal of scientific *assessment* is quite different, namely to help actual stakeholders to design better strategies and policies to cope with a particular problem (Farrell et al., 2001). The design of the assessment has to respond to the needs of the particular stakeholders who might use it, assuming they are known (Farrell and Jäger, 2005). Since even for a particular place, different stakeholders will want to know different things, the task can become every bit as challenging as that of designing scientific research (Schröter et al., 2005b). In short, scientific research is the task of developing theory about how the world works, while the task of scientific assessment—no less important a task—is making that theory accessible and useful.

Scholars describe assessment primarily as the social process, one that links scientific knowledge to policy-making (Clark et al., in press). As has become clear through numerous case studies, the processes that help to give rise to a successful assessment—one that actually has an impact on the policy-making process—are not necessarily the same as those that give rise to high quality scientific research (Cash, 2000). Assessments are more likely to be influential when they meet three criteria: they must provide information that is *salient* to decision-makers, they must be *credible*, and they must be socially and politically *legitimate* (Cash et al., 2003; Cash et al., in review). Salient information is that which matters to decision-makers. Thus, the temporal and spatial scale of the assessment must fit the temporal and spatial scale of decisions available to specific actors. In the case of Peruvian fisheries, for example, information about an approaching El Niño was extremely salient to banks that provided loans to operators of fishing boats, since it informed them that the risks for the coming season had changed. For the operators of the fishing boats themselves, however, the information was not salient, since there was nothing they could do with it; it was too late to find alternative sources of income (Broad, 1999). Information becomes

credible when people believe both the messenger and the message. Often, organizations with personal ties, not just to the scientific community, but also to the user community, can help maintain credibility of an assessment, even when users have reason to disbelieve it (Guston, 2001). Finally, users often only accept information when it comes from a socially and politically legitimate source. In debates during the 1980s on acid rain in Europe, for example, an integrated model developed at the International Institute for Applied Systems Analysis (IIASA) in Austria, not closely linked with any country either substantially causing or suffering from transboundary air pollution, was seen as more legitimate a tool for policy-makers than one developed in England, a major exporter of pollution (Patt, 1999b).

Global change vulnerability assessment highlights the need for a user and purpose driven process, because there are many different questions that the process can answer. The commonly assumed goal of vulnerability assessment is to inform the decision-making of specific stakeholders about options for adapting to the effects of global change (Metzger et al., 2005a). However, this is not always the only goal, and other objectives may also be in focus. We identify four typical reasons that people conduct vulnerability assessment, which we describe below as ideal types. In reality, of course, the boundary between the different goals is likely to be blurred, and one assessment will be undertaken for more than one purpose.

3.1 Assessing vulnerability to improve adaptation

The main goal of vulnerability assessment often is to help policy-makers minimize harm by adapting to ongoing or anticipated changes. Depending on the scale at which the policy-makers are acting, assessment of this sort can potentially be useful in two ways. First, if the spatial scale of the decision-makers is the same as that of the basic type of vulnerability, then the assessment can be useful by describing the elements of the system that are sensitive to change or may exacerbate harm, and by exploring the potential consequences of specific interventions to modify these elements (Parson et al., 2003). For example, one can describe the elements of coastal communities, including their systems of governance and social division of labor and responsibility, which make such communities more or less vulnerable to potential flooding (Adger, 2000). In this case, comparing the relative vulnerability of the place under study with that of other locations becomes useful when it illustrates the potential for making improvements. For example, following the hurricanes of 2005 that destroyed much of New Orleans and the United States Gulf Coast, there were many newspaper stories illustrating how other industrialized coastal regions, such as in the Netherlands, had made themselves less vulnerable through better-functioning infrastructure. These reports allow decision-makers to learn from the experiences of other communities that are similarly situated with respect to the same type of environmental risk.

Second, the spatial scale of the vulnerability assessment that seeks to promote adaptation may be aimed at decision-makers operating at a spatial scale that is larger than that of the basic type of vulnerability. These assessments are about comparing different places, and, in theory, should help decision-makers to prioritize efforts, directing resources at the places that are most vulnerable. To return to the example of New Orleans, maps prepared in advance of the storms indicated those neighborhoods that would be most severely flooded, and where the residents would be least likely to evacuate on their own. Such maps, if they had been used, could have allowed first evacuation teams and then rescue teams to direct a larger share of their efforts at these neighborhoods. At a much larger spatial scale, studies of entire countries can indicate which regions are most vulnerable to the effects of climate change and other social stressors, to help national level decision-makers make decisions to assist the most vulnerable regions (O'Brien et al., 2004a; Schröter et al., 2005a; Zebisch et al., 2005). This type of assessment often requires the

development of vulnerability indicators, which can be communicated via maps, charts, or tables, identifying places or sectors that are most vulnerable (Metzger et al., 2005a; Metzger et al., 2004).

Within the class of vulnerability assessment targeted towards improving adaptation, there are thus two very different criteria for judging success. In the case of that aimed at local level decision-makers, did the assessment provide them with the information about the system that they needed in order to make preparations or changes? Did the assessment offer them examples of successful policies, perhaps those implemented in other communities, which could be useful? Did the assessment adequately explore the uncertainties associated with trying to predict the consequences of interventions to a complex adaptive system? In the case of those assessments aimed at mapping relative vulnerability, it is valid to ask whether governments actually engage in prioritizing one community over another based on scientifically derived, and very uncertain, indicators (Patt et al., 2005a). Hence, what are the decisions that policy-makers, embedded in a contested political space, actually would take in response to a comparative assessment of vulnerability? Is the information provided by the vulnerability assessment useful to prioritize different regions' concerns in a fair and reliable way?

3.2 Assessing vulnerability to frame the climate change mitigation problem

At the international level, humankind must decide what degree of climate change to create, through the emission of greenhouse gasses. To some extent this decision hinges on an assessment of the damages that climate change would create, weighed against the economic growth that GHG emissions, unencumbered by mitigation policies, create. Thus, it is import to assess damages that may occur to human-environment systems from continued climate change.

Traditionally, this assessment of damages was within the scope of impact assessment (Carter et al., 1994; Kates et al., 1985). Climate change impact assessment is the natural cousin of the ubiquitous Environmental Impact Statement, whereby economic actors project the consequences of their actions. The target audience for impact assessment is the policy-making community concerned with climate mitigation. Although large countries such as the United States have commissioned their own domestic impact assessments (National Assessment Synthesis Team, 2001), mitigation is at its core a global problem, and hence the scale of impact assessment is typically seen as global (Schröter et al., 2005b). The goal of climate change impact assessment is to develop estimates of the total and marginal costs arising from various levels of global climate change, assuming various sets of background conditions.

The line between vulnerability assessment and impact assessment is fuzzy. Vulnerability assessment, one may argue, ought to be more precise about the potential for adaptation (Füssel and Klein, in press), about the risks of extreme events that could overwhelm local communities, the interconnections between human systems and environment systems (Turner, 1991; Turner et al., 2003b), or the potential for harm flowing from multiple causes (Turner et al., 2003a). In practice, however, impact assessment often does many of these (Jones, 2001), and vulnerability assessment often does not (Downing, 2000). It is not surprising, then, that many assessment claim to be of both impacts and vulnerabilities, and do not draw a sharp distinction between them (McCarthy et al., 2001).

A successful vulnerability assessment of this type, then, is one that manages to present credible estimates of aggregate societal damages to climate change, in such a way as to influence policy-makers concerned with global mitigation targets. Indeed, it can be a valid criticism of this type of

assessment that it provides too much detail on local scale impacts or opportunities, such that policy-makers lose the forest for the trees.

3.3 Assessing vulnerability to address social injustice

A third reason to assess vulnerability is to address social injustice, by exposing the degree to which global forces are negatively affecting the plight of the poor (Kasperson and Kasperson, 2001). Most researchers expect climate change to have the greatest impacts on developing countries, for several reasons (Kasperson, 2001; McCarthy et al., 2001; Watson et al., 1998). First, people in developing countries are far more reliant on agriculture for their livelihoods, compared to people in industrialized countries. In the United States, for example, less than 3% of the population is engaged in farming, whereas in most developing countries the majority of people earn their livelihood from the land (National Assessment Synthesis Team, 2001; Ribot et al., 1996). Agriculture, especially rain-fed agriculture, is extremely sensitive to changes in temperature, precipitation, and other climatic factors (Antle, 1995). Second, many developing countries already have unsustainable patterns of land-use. In rural areas, erosion from drought, wind, and rain is already a problem, something that climate change could exacerbate (Downing, 1991; Luers et al., 2003). In urban areas, millions of people live in poorly planned peri-urban settlements where flooding, landslides, and other risks are a frequent problem (Boullé et al., 1997; Kasperson et al., 1995; Smyth and Royle, 2000). Third, developing countries are often in a state of rapid social change, meaning that they do not have the social institutions to maintain stability in society when physical harm occurs (Adger, 1999). Fourth, developing countries often lack the capital—physical, human, or financial—to invest in adaptation to changing conditions (Brooks and Adger, 2004).

Given that the people who are already the worst off are likely to suffer disproportionately, and that those perceived as causing the harm in the first place—through the emission of greenhouse gasses—are relatively wealthy, there is a strong moral argument for rich countries assisting poorer ones to adapt to climate change (Kasperson and Kasperson, 2001). Some have suggested, based on these moral arguments, that part of the international policy response ought to be in providing economic relief to developing countries hardest hit by climate change, above and beyond that already provided in the area of disaster assistance, development assistance, and the Clean Development Mechanism to assist in creation of low emissions energy projects (Müller, 2002). Even though such a funding mechanism does not yet exist, one potential goal of comparative vulnerability assessment is prioritizing regions that may be in particular need for such a program.

Evaluating the success of such an assessment is difficult, since it is not clear who the audience is, and what decisions an assessment of this type are trying to influence. Even though the primary stakeholders are the poor themselves, the assessments may mostly be communicated to outsiders that feel a sense of responsibility or a strategic need to act upon vulnerability of others, and that may have the means to make a difference. We may expect this type of vulnerability assessment to be prepared by advocacy organizations, where the audience for the assessment is the general public in wealthy countries, and the purpose is to build awareness for the injustice flowing from climate change (Patt, 1999a). More often, examining social justice would be the collateral purpose of an assessment aimed at helping specific stakeholders to adapt, namely also giving them the political arguments to ask for assistance with that adaptation (O'Brien et al., 2004a; Suarez and Ribot, 2003) The success of such assessments then needs to be judged by the question whether they actually shed light on the causalities resulting in vulnerability. Such assessments

should point out the responsibility or capacity of actors both outside and within the system to improve the situation, and ideally make suggestions on which strategies to follow.

3.4 Assessing vulnerability to conduct scientific research

The fourth reason to conduct a vulnerability assessment is to learn about the system. In this case, the vulnerability assessment becomes the vehicle to conduct basic scientific research, creating value not just for the relevant stakeholders, but also for the scientific community in general. Because of this type of work, the boundary between scientific assessment and scientific research is necessarily fuzzy.

There are three reasons for trying to conduct basic research in the context of a vulnerability assessment. The first is that the vulnerability assessment provides the resources to conduct research. For example, vulnerability assessment allows for access to stakeholders. Since they will hopefully benefit from the assessment they have an incentive to work with the scientists who are involved. In a study on the use of seasonal climate forecasts in southern Africa to reduce vulnerability, researchers organized community workshops to explore the usefulness of the forecasts. The stakeholders attended the workshops over multiple years, because they felt that they benefited from the information being communicated there (Patt and Gwata, 2002). Ultimately, however, one of the strongest research findings of that project was not on the uses of the forecast, but on the benefits of the communication method used in the workshops, a valid social science research question (Patt et al., 2005b). The vulnerability assessment had provided the opportunity to compare people hearing the same information in different forms. Furthermore, in order to conduct a good local vulnerability assessment, it is necessary to collect a great deal of data about the current practices and historical conditions in a particular place or set of places. While one use of this information can certainly be to estimate present and future vulnerability, the information in general, in particular the historical or comparative information, can often be of general use in the study of historical vulnerability trends (Ribot et al., 1996). Similarly, the methods used to assess vulnerability, including spatial analysis, modeling, and mapping, often overlap with the same tools used in basic scientific research. A recent assessment of the vulnerability of European terrestrial ecosystem services, for example, made heavy use of a variety of downscaled climate, land-use, and environmental models (Schröter et al., 2005a). The development of these models for the purpose of the assessment, which was funded by the European Union and which fed into vulnerability-related decision-making, also was beneficial for basic scientific research using the same modeling tools.

The second reason to conduct scientific research within the context of a vulnerability assessment can be to learn generalizable knowledge about vulnerability. The exercise of mapping vulnerability to multiple threats, as described in this volume and in (O'Brien et al., 2004a), is often both an assessment and a research exercise. In this case, the interesting hypotheses are whether the projections of increased vulnerability made because of climate change overlap spatially with similar projections made on account of globalization and trade liberalization. To the extent they do, it alerts other assessment teams, working elsewhere, to pay attention to similar patterns where they are working. Hence, it potentially adds to the understanding of vulnerability.

The third reason is to improve the practice of vulnerability assessment. For example, many assessments of vulnerability that are published in the primary scientific literature are first attempts at using new methodologies to assess vulnerability (Luers et al., 2003; Metzger and Schröter, 2005 (in review); Metzger et al. 2005 (in press); O'Brien et al., 2004b). Only by going through the process of testing new methods in the process of an actual vulnerability assessment

can researchers learn whether the methods work, hopefully in satisfaction of one of the other three purposes already listed. In such pilot projects, one benefit is the information about the assessment methodology, while the immediate value to stakeholders becomes a data point in that study. The primary question to judge success of such projects is then whether they increased our understanding of vulnerability, or any components of vulnerability and whether they have helped us learn about appropriate methods to undertake vulnerability assessment.

3.5 Common denominators for vulnerability assessment

Vulnerability assessments can be most salient, legitimate, and credible to policy-makers, and hence most successful at productively influencing decision-making, when they fulfill the specific purpose or purposes for which they were undertaken. The information that is sought from the vulnerability assessment should determine the methodology for undertaking it, such as what data the scientists choose to examine, and how they examine them. Since there are a range of different purposes for undertaking vulnerability assessment, each with a different set of information needs, the methods that are appropriate for a particular vulnerability assessment are necessarily highly variable. Moreover, in almost all cases the information that fulfills the purpose of the assessment is only a subset of potential exposure, sensitivity, and adaptive capacity.

Consider briefly each of the four purposes already listed. The first kind of assessment is there to guide the first efforts at adaptive changes. In this case stakeholders need a rich description of the changes, with the focus of comparing alternative potential adaptive changes against each other, along with the challenges involved in undertaking each one. Stakeholders need information about multiple adaptive strategies, which they would begin now or later, and how to implement these. The second kind of assessment answers the question: what will be the effects of climate change given different mitigation options, and hence which mitigation options are better than others? The purpose of the assessment may be to inform global scale policy makers, or to persuade individual citizens that their own self-sacrifice is worthwhile. In either case, the relevant question is the extent to which people's lifestyles will be affected; changes of any sort—whether mitigation today or adaptation in the future—are costly, and apparently many people would like to change as little as possible. The challenge for assessment is to juxtapose descriptions of the mitigative or adaptive changes society will have to make, one way or another, so that the choice of which to engage in becomes clearer. What is needed is a rich description, and in some cases quantification, of those changes. The third kind of assessment, revealing social inequity as a result of climate change, needs to focus on who is able to make, request or force what changes, and comparing these with the responsibilities each group of people has had in the past. Again a rich description of adaptation is required, but the focus of comparison is between groups of people. The fourth type of assessment—undertaking scientific research—is not really assessment at all, since it will not necessarily benefit the people in the place of study, but rather the scientific community and humanity in general. If scientific research is the sole purpose of the assessment, which may be rarely the case, a rich description of the particular adaptations that the local people will make is not called for. The goal is rather a description that is general enough to be applied to other locations, times, and circumstances. Clearly, each of these types of assessment requires collecting and communicating a very different set of information, through a different method. Even in a single geographical region, it is likely that several different vulnerability assessments will be necessary, in order to answer different sets of questions.

We can ask ourselves: if the Norse Greenlanders were to commission a vulnerability assessment, what would they have needed to know in order to survive? Most likely many things, a collection of knowledge about ongoing climate changes, the fragility of Greenland soils, and hints about

how to learn to live with the Inuit as good neighbors. What they probably did not need was a single number indicating the summation of threats to their livelihood.

As counterintuitive as it may seem, an assessment can become the most confusing, can lose the most credibility, and can generate the most controversy when it delivers aggregate indicators, claiming these to represent measures of vulnerability itself. Indicators can be very useful, but will be ones most closely suited to the specific questions posed by stakeholders and interpreted by scientists. Since the questions and their interpretations differ from assessment to assessment, the necessary indicators must as well. Each of these indicators serves a valuable purpose, but the purposes are different. On the one hand it generates a great deal confusion when different assessment teams report a variety of indicators, each of which is suitable for the specific questions they are answering, and yet call all of these different indicators by the same name, namely vulnerability. On the other hand, rarely will any of these indicators' quantitative values match the emotional sense of vulnerability that many stakeholders feel, or deny. Successful vulnerability assessments, we suggest, can avoid confusion and conflict by labeling their output something other than vulnerability itself.

4 Outline for the book

We are proposing a model of vulnerability assessment that contains great diversity in its definition, formalization, and use of indicators of vulnerability. Rather than suggest a single set of guidelines to follow that applies a general theory of vulnerability, we suggest that there are many different kinds of assessment and indicators that are appropriate, each for a specific set of questions.

Against this backdrop of diversity in the concept of global change vulnerability, there are some general lessons to be learned for the practice of vulnerability assessment. The successful assessments are those where the scientists are able to focus on the specific questions their stakeholders need answered, in an organic *ad hoc* manner. Doing so, we suggest, requires paying attention to several points. First, the study of contemporary global change vulnerability can best be seen as an act of policy analysis, rather than an exercise of social and systems science research. Being within the domain and discourse of policy analysis eliminates the need for generalizable and broadly applicable results, but it does mean that discussions of vulnerability constantly raise questions that involve both facts and values. Second, scientific assessment, compared to scientific research, requires a continual open dialogue involving not only scientists but all relevant stakeholders. The legitimacy of the vulnerability assessment depends on the transparency of the process by which this dialogue takes place. Third, vulnerability assessments must be practical. In particular, the spatial and temporal scale of the assessment needs to match the scale of decision-making. This, in turn, has implications for the choice of indicators used to describe vulnerability.

Each of these points may seem rather obvious, but actually putting them into practice raises a number of design issues for vulnerability assessments. What we offer in the remainder of the book are examples of how other assessments, serving a wide diversity of stakeholders and their respective purposes, have succeeded or failed in implementing them. Each of the following chapters illustrates at least one of the issues that we have raised in this introduction. In sum, they illustrate both the diversity of methods needed for vulnerability assessment and the presence of some common denominators.

Evan Fraser in chapter 2, *The house is both empty and sad: Social vulnerability, environmental disturbance, economic change, and the Irish Potato Famine*, demonstrates how the study of an historical case can improve our theory of vulnerability. The study applies a social concept (the theory of entitlement, (Sen, 1981)) and an ecological concept (the theory of panarchy (Gunderson and Holling, 2002)), to analyze Irish historical vulnerability and to identify the multiple social and environmental causes and intertwined processes that led to suffering. The theory of panarchy is an attempt to capture the likelihood of a non-linear shift in ecosystems that is currently being tested by application in a series of case studies undertaken by a research network known as the Resilience Alliance (Ostrom, 2004). The author shows that the theory of vulnerability to climate change can learn from both of these theories (and hence, implicitly, from the Irish case study), and that these theories suggest a set of features of a system that may be useful indicators for assessing vulnerability.

Ian Holman and Lars Otto Næss in chapter 3, *Vulnerability assessments in the developed world: the UK and Norway,* compare assessments of vulnerability that took place in Norway and United Kingdom. Rather than comparing vulnerability in these two places, the chapter compares the approaches taken, and evaluates their effectiveness. It suggests that the UK assessment may have been more successful, partly because it engaged stakeholders, and partly because the degree to which stakeholders recognized global change as an area of concern was already quite advanced. In Norway, by contrast, the idea that the country could be vulnerable to global change was still new, and the assessment was driven by the curiosity of scientists, rather than by the government and local stakeholders. This chapter makes the point that the mandate of the study influences the manner in which the assessment is done, and ultimately its immediate usefulness to stakeholders.

Matthieu Craye and Silvio Funtowicz in chapter 4, *Dealing with scientific uncertainty in relation to environmental risk and vulnerability: between 'normal' and 'reflexive' (or 'post-normal') practices*, highlight the different roles that uncertainty plays in scientific research and in reflexive scientific assessment. In the traditional approach to applying scientific research to policy, uncertainty was seen as a cause for inaction, and hence undermined the value of the assessment. In a reflexive assessment, by contrast, uncertainty becomes the starting point for discourse examining society's values and goals, and the relationship between knowledge and those goals.

Siri Eriksen, Florence Nazare, Coleen Vogel, Franziska Steinbruch, and Gina Ziervogel in chapter 5, *Vulnerability assessments in the developing world: Mozambique and South Africa*, describe a variety of efforts to assess vulnerability in South Africa and Mozambique, two bordering countries. First, the chapter describes the common features of vulnerability in the two countries. Next, the chapter presents several different assessments that were made, and how each responded to stakeholder needs at a variety of scales, including a multi-stressor approach to vulnerability. Importantly, the assessments dealt explicitly with issues of development, as an essential element of global change and adaptation. However, the assessments also illustrate how a variety of approaches was needed, even within a limited geographical area, requiring a diversity of indicators to answer stakeholders' respective questions.

Martin Welp, Antonella Battaglini, and Carlo Jaeger, in chapter 6, *Social relevance of vulnerability assessment: role of stakeholder dialogues in defining dangerous levels of climate change*, examine the use of vulnerability assessment in the process of building broad based consensus around mitigation goals. In this case, the focus was truly global, without need for fine scale local investigation, matching the global scale at which consensus was sought. The role of vulnerability information and regional representation was in helping to build consensus that

would be later seen as legitimate. In reaching consensus, anecdotal information played at least as important a role as aggregate indicators and uncertainty ranges.

Dagmar Schröter in chapter 7, *Vulnerability to changes in ecosystem services*, identifies ecosystem services, which are vital to the function of a human-environment system, as an important subunit of analysis. The author provides historical examples of times when societies have been vulnerable due to a loss in ecosystem services, and the reasons for their mismanagement. The chapter then turns to a recent European project studying terrestrial ecosystem services. The author shows that the focus on ecosystem services served two purposes: providing a rationale to mitigate, and the basis of understanding to guide adaptation. In some cases, there were identifiable actors who could respond to the information to adapt, such as forest managers and agriculture planners, whose time horizon matched that of the assessment. For other ecosystem services or vulnerabilities (e.g. water stress) there was no limited group of stakeholders, and in this case, the assessment was taken up by the media for its implications for mitigation

Hans-Martin Füssel and Kristie L. Ebi in chapter 8, *Vulnerability of human health*, show that global change vulnerability assessment often focuses on a particular outcome—loss of health. Health is an area of concern that already has an entire policy community and infrastructure already established. In order to assess global change vulnerability with respect to health, it is important to link the work to other health related work in non global change related contexts. This is consistent with other chapters in this volume, in particular chapters 5 and 9, which demonstrate the importance of relating outcome-oriented assessments to pre-existing concerns about development.

Maxx Dilley in chapter 9, *Cross-scale decision-support for managing climate-related risks: a framework and case studies in operationalizing the use of climate information*, describes vulnerability assessment to assist adaptation from a risk management perspective. To have immediate effect on policy-making, the author demonstrates, the scope of decision-support systems needs to be linked to that of identifiable actors and policy institutions, rather than to a more general issue domain (such as climate, or poverty). Being specific about stakeholders—their domain of decision-making and their information needs—is one of the central challenges. Consistent with the conclusions from chapters 5 and 8, it is essential that the climate-related information link to these stakeholders' preexisting areas of concern.

Robin Leichenko and Karen O'Brien in chapter 10, *Mapping double exposure to climate change and trade liberalization as an awareness-raising tool*, describe an assessment undertaken in India. By mapping indicators of vulnerability, the assessment raises the issues of differential vulnerability, the potential of some communities to suffer great harm, and the injustice associated with various aspects of global change. Such a mapping exercise does not necessarily assist local communities to adapt, nor does it suggest particular mitigation targets, but rather serves to build awareness of the risks many people may face unless pro-active steps are taken.

Lilibeth Acosta-Michlik and Mark Rounsevell in chapter 11, *Agent based modeling as a tool to explore dynamic vulnerability*, describe a project that links vulnerability assessment with advanced theoretical research. One of the cutting edge areas of scientific research is the study of complex adaptive systems, and an important tool to develop and test hypotheses about their functioning is the agent based model. A case study of a Portuguese village's potential responses to climate change and globalization shows how a vulnerability assessment, undertaken with

stakeholders, can be an effective vehicle for parameterizing an agent based model, and carrying out basic research on the functioning of complex adaptive systems.

Jochen Hinkel in chapter 12, *A framework for analyzing integrated methodologies of vulnerability assessment*, proposes a framework for tackling some of the confusion that the diversity of approaches toward vulnerability and vulnerability assessment creates. Vulnerability assessments are almost always *ad hoc*, responding to particular stakeholder needs. They also contain a great number of separate tasks and pieces of analysis, and often bridge national and scientific cultures. Participants in such projects need to clarify what their own roles are, even if they have participated in other vulnerability assessments in the past. Given constrained project budgets and timelines, this limits the effectiveness of assessments. Vulnerability assessments could thus benefit from describing their own structure and process with a common syntax, such as the one the author proposes in this chapter. This would better allow all participants to understand their respective roles, allow for more effective and rapid integration, and ultimately more effective assessment.

The selection of chapters is neither complete nor representative. We have chosen them first because we believe they paint a rough sketch of the diversity of vulnerability assessment, and in doing so offer the reader numerous hooks onto which to latch. Second, we have chosen them because the authors were able to spare the time to write them. The point is, the demand for useful knowledge about how to cope with the unprecedented changes taking place on the planet far outstrips the supply of people to research and convey that knowledge. Every vulnerability assessment is undertaken with a conviction that it is necessary, and a hope that it can make a difference to real people, and the work needed to translate conviction and hope into reality often seems endless. Our hope is that by taking a minute to come up for air, we can reinvigorate the practice.

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