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Adaptation, adaptive capacity and vulnerability

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Abstract

This paper reviews the concept of adaptation of human communities to global changes, especially climate change, in the context of adaptive capacity and vulnerability. It focuses on scholarship that contributes to practical implementation of adaptations at the community scale. In numerous social science fields, adaptations are considered as responses to risks associated with the interaction of environmental hazards and human vulnerability or adaptive capacity. In the climate change field, adaptation analyses have been undertaken for several distinct purposes. Impact assessments assume adaptations to estimate damages to longer term climate scenarios with and without adjustments. Evaluations of specified adaptation options aim to identify preferred measures. Vulnerability indices seek to provide relative vulnerability scores for countries, regions or communities. The main purpose of participatory vulnerability assessments is to identify adaptation strategies that are feasible and practical in communities. The distinctive features of adaptation analyses with this purpose are outlined, and common elements of this approach are described. Practical adaptation initiatives tend to focus on risks that are already problematic, climate is considered together with other environmental and social stresses, and adaptations are mostly integrated or mainstreamed into other resource management, disaster preparedness and sustainable development programs.

Keywords: Adaptation; Adaptive capacity; Vulnerability; Applications; Community; Participatory; Bottom-up; Implementation; Mainstreaming

1. Introduction

This paper reviews the concept of adaptation in the context of adaptive capacity and vulnerability of human systems to global changes, especially climate change. A particular focus is on recent developments in scholarship that contribute to practical applications of adaptation and adaptive strategies. Kelly and Adger (2000), Füssel (2004) and O'Brien et al. (2004a) distinguish applications of research relating to vulnerability, including studies that relate to adaptation. The applications of interest here are those that contribute directly to adaptation initiatives to tangibly influence the vulnerability of human communities or societies to conditions related to climate change.

Adaptation in the context of human dimensions of global change usually refers to a process, action or outcome in a system (household, community, group, sector, region, country) in order for the system to better cope with, manage or adjust to some changing condition, stress, hazard, risk or opportunity. Numerous definitions of adaptation are found in climate change literature, mostly variations on a common theme. Brooks (2003, p. 8), describes adaptation as "adjustments in a system's behavior and characteristics that enhance its ability to cope with external stress". Smit et al. (2000, p. 225), in the climate change context, refer to adaptations as "adjustments in ecological-socio-economic systems in response to actual or expected climatic stimuli, their effects or impacts." Pielke (1998, p. 159), also in the climate context, defines adaptations as the "adjustments in individual groups and institutional behavior in order to reduce society's vulnerability to climate." Based on their timing, adaptations can be anticipatory or reactive, and depending on their degree of spontaneity they can be autonomous or planned (Fankhauser et al., 1999; Smit et al., 2000).

The concepts of *adaptation*, *adaptive capacity*, *vulnerability*, *resilience*, *exposure* and *sensitivity* are interrelated and have wide application to global change science. Analyses range in scale from the vulnerability and

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adaptation of an individual or household to a particular climate stress such as drought, through the vulnerability and adaptation of a community to multiple stresses, to the vulnerability of humankind (or the global ecosystem) to all stresses and forces. Applications also vary by the phenomena of interest (biological, economic, social, etc.), and by time scale (instantaneous, months, years, decades, centuries). This paper looks closest at applications to human systems and human–environment systems, including communities, households, groups, sectors, regions and countries. While this focus includes the natural resource systems upon which societies depend, we do not review applications relating to the vulnerability and adaptation of physical or biological systems even though some of the concepts (particularly adaptation) have long, if contested, use in those fields (Smit et al., 2000; Smit and Pilifosova, 2003). It is in ecological systems that the resilience concepts have been most developed (Berkes et al., 2003; Holling, 2001; Gunderson and Holling, 2002). The resilience of ecosystems and socio-ecological systems is reviewed by Folke (2006).

Practical initiatives that tangibly address and improve societal adaptive capacity, thereby reducing vulnerability, are commonly expected to be evident at the community scale (Kates, 2000; Kelly and Adger, 2000; Ford and Smit, 2004). There are examples of international and national initiatives that have potential to contribute to the reduction of vulnerabilities of people, and their effects should be apparent in communities. For example, National Adaptation Plans of Action (NAPAs), if effectively implemented, should generate results evident in communities. *Community* is used here to mean some definable aggregation of households, interconnected in some way, and with a limited spatial extent, analgous to Coombes et al.'s (1988) use of the term "locality."

The following sections provide a brief overview of the concept of adaptation as it has been employed in a range of fields, and as it relates to adaptive capacity and vulnerability in the context of climate change. Then several purposes of adaptation analysis are distinguished in the climate change field, including one type of application that aims to contribute to actual adaptation strategies. The paper concludes with a review of analytical approaches which have been developed to facilitate this practical purpose.

2. Treatment of the adaptation concept

The term adaptation, as it is presently used in the global change field, has its origins in natural sciences, particularly evolutionary biology. Although the definition of adaptation in the natural sciences is disputed, it broadly refers to the development of genetic or behavioral characteristics which enable organisms or systems to cope with environmental changes in order to survive and reproduce (Futuyama, 1979; Winterhalder, 1980; Kitano, 2002). Individual adaptations (or adaptive features) are the features of organisms which have developed to ensure survival (Dobzhansky et al., 1977; O'Brien and Holland, 1992). Consideration of adaptation within natural sciences encompasses scales from the organism or individual to the population of a single species or an entire ecosystem (Krimbas, 2004).

The application of the term adaptation to human systems has been traced to the anthropologist and cultural ecologist Julian Steward, who used "cultural adaptation" to describe the adjustment of "culture cores" (i.e. regional societies) to the natural environment through subsistence activities (Butzer, 1989). O'Brien and Holland (1992, p. 37) define the process of adaptation as "one by which groups of people add new and improved methods of coping with the environment to their cultural repertoire". Denevan (1983, p. 401) considers (cultural) adaptation as a "process of change in response to a change in the physical environment or a change in internal stimuli, such as demography, economics and organization", thereby broadening the range of stresses to which human systems adapt beyond biophysical stress.

Social science treatment of adaptation in human systems has been concerned with "success" or survival of a culture. Anthropologists and archeologists suggest that adaptation is a consequence of selection acting on variation through cultural practices (adaptations) which have historically allowed a culture to survive (O'Brien and Holland, 1992). Cultural practices are thus equated with genetic characteristics in the natural sciences; in this Darwinian view, a group which does not have adequate methods of coping with environmental stress will not be able to compete for scarce resources and will fail to continue. In this treatment of the term, a cultural practice is an "adaptation" only if it developed to overcome stress, thereby distinguishing adaptations from "adaptive features" that allow societies to function within their environments regardless of whether or not they evolved as a result of selection (O'Brien and Holland, 1992).

In more recent social science work, cultural practices that allow societies to survive (and, beyond that, flourish) are considered adaptations which can be distinguished based on behavior and (technological) innovation (Denevan, 1983). It is recognized that societies adapt to a range of stimuli including, but not limited to, environmental stress. Cultures (or societies) which are able to respond to or cope with change quickly and easily are considered to have high "adaptability" or "capacity to adapt" (Denevan, 1983).

The concept of adaptation has been used both explicitly and implicitly in the social sciences, including in natural hazards, political ecology, and the entitlements and food security scholarship. Some scholars of adaptation have employed the concepts and terminology of biophysical ecological change with a focus on flows of matter, energy and information (e.g. Odum, 1970) and related concepts of resilience, equilibrium and adaptive management (e.g. Holling, 1986). Others, particularly in the natural

hazards perspective, have focused on perception, adjustment and management of environmental hazards (e.g. Burton et al., 1978).

Adaptation is usually implicit in the political ecology field. The relationships between ecosystems and political economy are often treated as issues of adaptive management of risks related to political and social power relations, resource use, and global economies (Blaikie and Brookfield, 1987; Sen, 1981; Walker, 2005). Work on entitlements and food security considers adaptation as a stress response in light of access to resources and the abilities of people to cope (Downing, 1991; Adger and Kelly, 1999; Adger, 2000). A key feature of this field is its demonstration of how the adaptive capacity of individuals or households is shaped and constrained by social, political, and economic processes at higher scales. Similarly, research on global environmental risk and the social amplification of risk places adjustments and adaptations in the context of human driving forces, biophysical constraints and the social, economic and political attenuation of risks (Kasperson and Kasperson, 2001, 2005; Pidgeon et al., 2003).

Conceptualizations of risks and their manifestation as disasters, including the pressure and release (PAR) model (Blaikie et al., 1994; Wisner et al., 2004), identify the environmental stresses of hazards and the progression of social forces that contribute to vulnerability, including those that relate to adaptive capacity. This view of environment–society coupled systems that specify the role of human adaptive responses is further developed in the vulnerability framework of Turner et al. (2003) and the access model of Wisner et al. (2004).

Analyses of adaptations in the climate change field emerged concurrently with the growing awareness of climate change itself. An early example is Butzer (1980) who considered "cultural adaptation" (human ingenuity including technological innovation and long-range planning) in light of predicted climate change and its anticipated impacts on world food supply. Since then, analyses of adaptation to changing climatic conditions have been undertaken for a variety of purposes (Kelly and Adger, 2000; Smit et al., 2000).

3. Purposes of climate change adaptation research

One common purpose of adaptation analyses in the climate change field is to estimate the degree to which modeled impacts of climate change scenarios could be moderated or offset (or "mitigated") by "adaptation to the impacts" (Parry, 2002; Mendelsohn et al., 2000; Fankhauser, 1998). These analyses address Article 2 of the United Nations Framework Convention on Climate Change (UNFCCC), which commits countries to mitigate greenhouse emissions in order to avoid "dangerous" anthropogenic changes in climate. Adaptations are considered to assess the degree to which they can moderate or reduce negative impacts of climate change, or realize positive effects, to avoid the danger. These analyses are usually undertaken at broad scales, where equilibrium or statistical models are used to estimate impacts with and without adaptation, in order to address the question: how serious or "dangerous" are specified scenarios of climate change (Dessai et al., 2003; Tubiello et al., 2000; Winters et al., 1998; Parry et al., 2001).

When analyzed for this purpose, adaptations are conventionally *assumed* or hypothetical, and their effect on the system of interest is estimated relative to the estimated impacts (e.g. in terms of costs, savings, etc.). For this use, the focus is on the *effect* of the assumed adaptations. The purpose is to estimate impacts of climate change, and to estimate the difference adaptation could make. This work does not empirically investigate adaptations, examine the actual processes of adaptation or adaptive capacity, explore the conditions or drivers that facilitate or constrain adaptations, nor document the decision-making processes, authorities and mechanisms involved in adaptation. It takes certain assumed or hypothetical adaptations and then estimates the effects they would have on the calculated impacts of conditions captured in the specified climate change scenarios (Tol, 1996; Arnell, 1999). The term vulnerability has sometimes been used to describe the estimated net or residual impacts (initial impact costs minus net adaptation savings).

A second body of scholarship focuses on specific adaptation options or measures, for a particular system subject to climate change stimuli. These analyses address the articles of UNFCCC that commit countries to "formulate and implement… measures to facilitate adequate adaptation to climate change" (Article 4.1). The purpose of these analyses is to assess the relative merit or utility of alternative adaptations, in order to identify the "best" or better ones (e.g. Dolan et al., 2001; Klein et al., 1999; Fankhauser et al., 1999; Niang-Diop and Bosch, 2004). The analysis involves selecting a suite of "possible adaptations", chosen by the researcher from hypotheses, observations, modeling, extrapolation, analysis, key informants or deductive reasoning. These possible adaptations are usually considered to be distinct and discrete, in order that they can be subjected to evaluation according to some common principles or criteria. Among the tools used to rank or rate the relative merit of possible adaptations are benefit-cost, cost effectiveness and multiple-criteria procedures. Common variables employed are benefits, costs, implementability, effectiveness, efficiency, and equity (Fankhauser et al., 1999; Feenstra et al., 1998; Smith et al., 1998; Adger et al., 2005a). Such analyses assume that there is, in practice, a process through which adaptations are selected and implemented, and that the relative evaluation analysis fits into this process. The focus of these studies is to rate or rank potential adaptations, but they rarely investigate the processes through which adaptation measures are undertaken, either in light of climatic change specifically (which is very rare) or as part of policy and decision-making processes to which adaptations to climate change might relate.

A third group of studies focuses on the relative adaptive capacity (or vulnerability) of countries, regions or communities, and involves comparative evaluation or rating based on criteria, indices and variables typically selected by the researcher (Van der Veen and Logtmeijer, 2005; O'Brien et al., 2004a; Kelly and Adger, 2000; Adger et al., 2004; Brooks et al., 2005; Rayner and Malone, 2001). Vulnerability is taken as the "starting point" rather than the residual or "end point" (O'Brien et al., 2004b), and it is assumed to be measurable based on attributes or determinants selected a priori. The expected application is that adaptation efforts should be directed to those areas with the greatest exposures or least adaptive capacity.

This work relates to UNFCCC Article 4.4, which commits developed country parties to "assist developing country parties that are particularly vulnerable to the adverse effects of climate change…". The main purpose of these studies is to provide an evaluation of the relative vulnerability (and/or relative adaptive capacity) of the countries or regions, usually using some kind of indicator, scoring, rating or ranking procedure. Thus, surrogate measures of exposure or sensitivity and elements of adaptive capacity for each system are estimated and then aggregated to generate an overall vulnerability "score" (or level or rating) for each system (Adger, 2006). The intent is to provide information for the targeting of adaptation initiatives, or the targeting of scarce resources.

In this third type of research, the analyst selects the factors or determinants of vulnerability or adaptive capacity (sometimes with local inputs), obtains measures on these (usually aggregate surrogates from available secondary data), adopts an aggregation function over the measures (usually summation) and calculates an overall vulnerability value for each system. This research does not aim to identify the processes, determinants or drivers of adaptive capacity and vulnerability as they function in each system—they are taken as given, and used as the basis for the rating or ranking analysis. Nor does this analysis substantively address the policy and decision-making processes that deal with the conditions that can alter adaptive capacity and vulnerability. It is implicitly assumed that the output—indications of the relative vulnerability or adaptive capacity—will have application in policy and decision-making, by identifying the countries or districts or areas with the greatest vulnerability or least adaptive capacity.

The purpose of the fourth type of analysis is to contribute to practical adaptation initiatives. Research that focuses on the implementation processes for adaptations is still not common; at least, it is not common under the label of "adaptation" research, and certainly not in the climate change field. There is a vast body of scholarship in the fields of resource management, community development, risk management, planning, food security, livelihood security, and sustainable development that deals with the actual practices and processes of adaptation, although the word "adaptation" may not be explicitly used (Sanderson, 2000; Gittell and Vidal, 1998; Alwang et al., 2001; Haimes, 2004).

By "practical application", we mean research that investigates the adaptive capacity and adaptive needs in a particular region or community in order to identify means of implementing adaptation initiatives or enhancing adaptive capacity. This enables the identification and development of particular adaptive measures or practices tailored to the needs of that community. The aim is not to score adaptations or measure relative vulnerabilities, nor to quantify impacts or estimate effects of assumed adaptations. Rather, the focus is to document the ways in which the system or community experiences changing conditions and the processes of decision-making in this system (or that influence the system) that may accommodate adaptations or provide means of improving adaptive capacity (Keskitalo, 2004; Ford and Smit, 2004; Sutherland et al., 2005; Vásquez-León et al., 2003).

In the climate adaptation field, this body of work is characterized by several distinctive features that are important to facilitate adaptation initiatives. It tends not to presume the specific variables that represent exposures, sensitivities, or aspects of adaptive capacity, but seeks to identify these empirically from the community. It focuses on conditions that are important to the community rather than those assumed by the researcher or for which data are readily available. It employs the experience and knowledge of community members to characterize pertinent conditions, community sensitivities, adaptive strategies, and decision-making process related to adaptive capacity or resilience. It identifies and documents the decision-making processes into which adaptations to climate change can be integrated. It is sometimes called a "bottom-up" approach in contrast to the scenario-based "top-down" approaches.

The distinctive motivation here is to identify what can be done in a practical sense, in what way and by whom, in order to moderate the vulnerability to the conditions that are problematic for the community (Pahl-Wostl, 2002; Moss et al., 2001; Morduch and Sharma, 2002). This work is not designed to be "scaled up" in the sense of generating an aggregate regional or global score or valuation of vulnerability or adaptation. The "scaling up" of this work would involve comparisons across communities or societies in order to identify those characteristics of communities and their environments that contribute to or moderate vulnerabilities, and the features of adaptive strategies that are effective.

One noteworthy development in this applied work on adaptation processes is that of "mainstreaming". The whole point of the work on adaptation processes is to have risks (and opportunities) associated with climate change (or other environmental changes) actually addressed in decision-making at some practical level. One of the fundamental findings from this work is that it is extremely unlikely for any type of adaptive action to be taken in light of climate change alone (Huq and Reid, 2004; Handmer et al., 1999; Morduch and Sharma, 2002; Huq et al., 2003).

There are now numerous examples of climate change risks being incorporated into existing policies, programs or decision-making processes related to resource management, community development, livelihood enhancements, coastal zone management, sustainable development and risk management. Practical climate change adaptation initiatives are invariably integrated with other programs, and often aim to enhance adaptive capacity.

4. Adaptation, adaptive capacity and vulnerability

Adaptation, whether analyzed for purposes of assessment or practice, is intimately associated with the concepts of vulnerability and adaptive capacity. A general conceptual model of vulnerability has emerged in the climate change scholarship, similar to the use of the concept more widely (Kelly and Adger, 2000; Downing, 2001; Turner et al., 2003; Smit and Pilifosova, 2003; Yohe et al., 2003; Adger, 2006). Consistent throughout the literature is the notion that the vulnerability of any system (at any scale) is reflective of (or a function of) the exposure and sensitivity of that system to hazardous conditions and the ability or capacity or resilience of the system to cope, adapt or recover from the effects of those conditions. These concepts are labeled in different ways and given different emphases in various fields. Adaptations are manifestations of adaptive capacity, and they represent ways of reducing vulnerability.

The basic *vulnerability* relationships are portrayed in Venn diagram format in Fig. 1. The larger sets represent the broader stresses and forces that determine exposure and sensitivity and shape adaptive capacity at the local or community level, denoted by the smaller embedded sets. The interaction of environmental and social forces determines exposures and sensitivities, and various social, cultural, political and economic forces shape adaptive capacity. The overlap recognizes that the processes driving exposure, sensitivity and adaptive capacity are frequently interdependent. The finer scale interaction of these

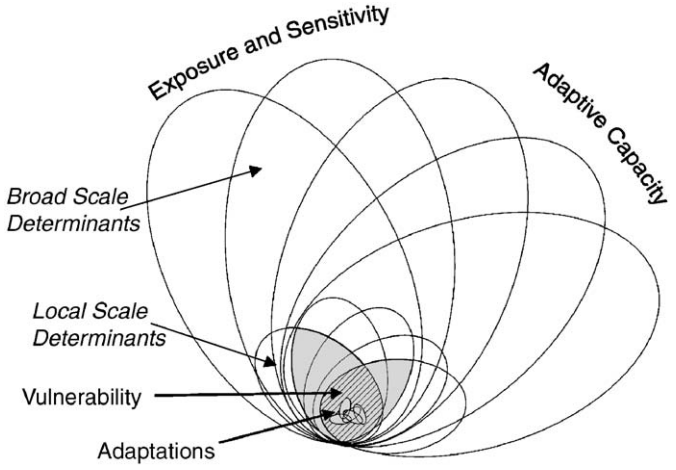

Fig. 1. Nested hierarchy model of vulnerability.

elements represents local vulnerability, and adaptations are particular expressions of the inherent adaptive capacity. Generally, a system (e.g. a community) that is more exposed and sensitive to a climate stimulus, condition or hazard will be more vulnerable, Ceteris paribus, and a system that has more adaptive capacity will tend to be less vulnerable, Ceteris paribus.

This conceptualization broadly indicates the ways in which vulnerabilities of communities are shaped. It does not necessarily imply that the elements of exposure, sensitivity and adaptive capacity can or should be measured in order to numerically compare the relative vulnerability of communities, regions or countries. Vulnerability, its elements of exposure, sensitivity and adaptive capacity, and their determinants are dynamic (they vary over time), they vary by type, they vary from stimulus to stimulus, and they are place- and system-specific.

Consistent with the literature, this conceptualization differentiates the two broad contributing elements of vulnerability, but does not suggest that these are unrelated. The model does not specify a priori particular factors, processes or functional relationships between exposure, sensitivity and adaptive capacity. It assumes they exist and are distinctive to particular places and times. Certainly, there are broad social, economic, political and ecological conditions that affect exposure, sensitivity and adaptive capacity, but at the community level these elements will be exhibited in diverse ways. Even for a particular system, vulnerability is unlikely to be the same for all stimuli, even all climatic stimuli (e.g. increasing temperature, floods, sea level rise, low-frequency droughts, high-frequency droughts, high-frequency extended droughts, etc.).

Exposure and *sensitivity* are almost inseparable properties of a system (or community) and are dependent on the interaction between the characteristics of the system and on the attributes of the climate stimulus. The exposure and sensitivity of a system (e.g. a community) to an environmental change risk (e.g. drought) reflect the likelihood of the system experiencing the particular conditions and the occupance and livelihood characteristics of the system which influence its sensitivity to such exposure. The occupance characteristics (e.g. settlement location and types, livelihoods, land uses, etc.), reflect broader social, economic, cultural, political and environmental conditions, sometimes called "drivers" or "sources" or "determinants" of exposure and sensitivity. Many of the determinants of occupance or sensitivity are similar to those that influence or constrain a system's adaptive capacity. A research challenge for practical adaptation work to characterize the exposure and sensitivity elements of vulnerability is to identify those processes of climate conditions and system occupancy dynamics that are considered to be problematic, risky or hazardous in some way to the community of interest. These are rarely known a priori.

Adaptive capacity is similar to or closely related to a host of other commonly used concepts, including adaptability, coping ability, management capacity, stability, robustness,

flexibility, and resilience (Smithers and Smit, 1997; Adger and Kelly, 1999; Smit et al., 1999; Jones, 2001; Fraser et al., 2003; Tompkins and Adger, 2004; Brooks, 2003; Füssel and Klein, 2006). The forces that influence the ability of the system to adapt are the drivers or determinants of adaptive capacity (Adger, 2003; Turton, 1999; Walker et al., 2002; Wilbanks and Kates, 1999; Blaikie et al., 1994; Kasperson and Kasperson, 2001). Local adaptive capacity is reflective of broader conditions (Smit and Pilifosova, 2003; Yohe and Tol, 2002). At the local level the ability to undertake adaptations can be influenced by such factors as managerial ability, access to financial, technological and information resources, infrastructure, the institutional environment within which adaptations occur, political influence, kinship networks, etc. (Watts and Bohle, 1993; Hamdy et al., 1998; Adger, 1999; Handmer et al., 1999; Kelly and Adger, 2000; Toth, 1999; Smit and Pilifosova, 2001; Wisner et al., 2004; Adger et al, 2001; Blaikie and Brookfield, 1987). Some determinants of adaptive capacity are mainly local (e.g. the presence of a strong kinship network which will absorb stress) while others reflect more general socio-economic and political systems (e.g. the availability of state-subsidized crop insurance).

Adaptive capacity is context-specific and varies from country to country, from community to community, among social groups and individuals, and over time. It varies not only in terms of its value but also according to its nature. The scales of adaptive capacity are not independent or separate: the capacity of a household to cope with climate risks depends to some degree on the enabling environment of the community, and the adaptive capacity of the community is reflective of the resources and processes of the region (Smit and Pilifosova, 2003; Yohe and Tol, 2002).

Adaptive capacity has been analyzed in various ways, including via thresholds and "coping ranges", defined by the conditions that a system can deal with, accommodate, adapt to, and recover from (de Loe and Kreutzwiser, 2000; Jones, 2001; Smit et al., 2000; Smit and Pilifosova, 2001, 2003). Most communities and sectors can cope with (or adapt to) normal climatic conditions and moderate deviations from the norm, but exposures involving extreme events that may lie outside the coping range, or may exceed the adaptive capacity of the community. Some authors apply "coping ability" to shorter term capacity or the ability to just survive, and employ "adaptive capacity" for longer term or more sustainable adjustments (Vogel, 1998). Watts and Bohle (1993) use "adaptability" for the shorter term coping and "potentiality" for the longer term capacity.

A system's adaptive capacity and coping range (one feature of capacity) are not static. Coping ranges are flexible and respond to changes in economic, social, political and institutional conditions over time. For instance, population pressure or resource depletion may gradually reduce a system's coping ability and narrow its coping range, while economic growth or improvements in technology or institutions may lead to an increase in adaptive capacity (deVries, 1985; Smit and Pilifosova, 2003; Folke et al., 2002).

The graphical representation (Fig. 2) shows that the coping range(in this case to deal with drought) can increase over time or decrease, for a variety of reasons. External socio-economic and political factors (e.g. war, the collapse of an institution such as a crop insurance program, loss of a key decision-maker) may lead to a narrower coping range. Furthermore, the cumulative effects of increased frequency of events near the limit of the coping range may decrease the threshold beyond which the system cannot cope/adapt/recover (Jones, 2001; Dessai et al., 2003). For example, two consecutive years of high moisture deficit which are not beyond the limits of the normal coping range present little problem in the present but require drawing on stored resources, and the consumption of these resources may subsequently narrow the coping range until they can be built up again, so a third and fourth year of moisture deficit of the same magnitude may well exceed the now smaller coping range.

Similarly, conditions which are within the coping range may introduce unforeseen side effects which will narrow the coping range. For example, a warm, wet year may be an ideal year for crop production and lead to high yields. Subsequent years of warm, wet conditions can, however, encourage the development of pest and fungal outbreaks and actually decrease yields and thus the coping range is reduced. Finally, a catastrophic event beyond the limit of the coping range may permanently alter the system's normal coping range if it is not able to recover from it. For example, consider a system that relies on irrigation water, captured in a dam. A very wet year, far beyond the normal conditions, may lead to the dam's failure, and thus the previous coping range cannot be returned to in a subsequent "average" year.

Adaptations are manifestations of adaptive capacity. Adaptations, or changes in the system to better deal with problematic exposures and sensitivities, reflect adaptive capacity. Clearly there are many forms and "levels" of adaptations, and these can be classified in many ways

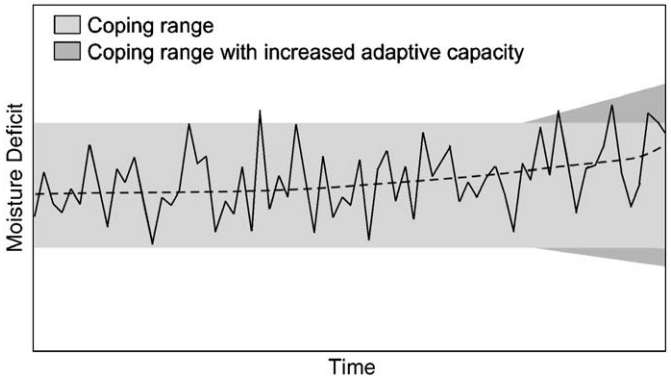

Fig. 2. Coping range and extreme events (based on Smit and Pilifosova, 2003).

including by timing relative to stimulus (anticipatory, concurrent, reactive), intent (autonomous, planned), spatial scope (local, widespread) and form (technological, behavioral, financial, institutional, informational) (Smit et al., 2000; Wilbanks and Kates, 1999; Smit and Skinner, 2002; Huq et al., 2003). It is also possible to distinguish adaptations according to the degree of adjustment or change required from (or to) the original system (Risbey et al., 1999). For an agricultural system facing water shortage exposures, a simple adaptation might be to use more drought resistant cultivars. A more substantial adaptation might be to shift away from crop farming to pastoralism. An even more substantial adaptation might be to abandon farming altogether.

The determinants of adaptive capacity are not independent of each other. For example, the presence of a strong kinship network may increase adaptive capacity by allowing greater access to economic resources, increasing managerial ability, supplying supplementary labor and buffering psychological stress. Similarly, economic resources may facilitate the implementation of a new technology and ensure access to training opportunities and may even lead to greater political influence. Individual determinants, thus, cannot be isolated: adaptive capacity is generated by the interaction of determinants which vary in space and time. The determinants of adaptive capacity exist and function differently in different contexts. For example, a strong kinship network may play an important role in a subsistence-based society, and quite a different role in a developed world agribusiness context where financial and institutional structures will influence adaptability.

To date, there is very little consensus (or documented support) for a robust, specific model of the elements and processes of local exposure, sensitivity, and adaptive capacity, beyond broad categories. The broad factors or determinants that influence sensitivities and constrain the abilities of communities to deal with hazards or stressful conditions are too general guide in practical adaptation programs. Community-based analyses have shown that the conditions that interact to shape exposures, sensitivities, adaptive capacities, and hence create needs and opportunities for adaptation, are community specific. For example, the factor "technology" may be relevant in all cases, but the way in which technologies influence vulnerabilities and the types of technologies that may be feasible or available and how they interact with political, social and economic processes invariably differ from community to community

5. From adaptation analysis to practice

Some general principles are now apparent from community-based vulnerability assessments aiming to contribute to practical adaptation initiatives. One is that the researcher does not presume to know the exposure and sensitivities that are pertinent to the community, nor does the research specify a priori determinants of adaptive capacity in the community. Rather, in this approach these are identified from the community itself. The methods require the active involvement of stakeholders, considerable effort to ensure legitimacy, information collection on community relevant phenomena and processes, the integration of information from multiple sources, and the engagement of decision-makers.

Variants of participatory, "bottom-up", experience-based assessment of community conditions have been employed in many fields including sociology, anthropology, geography, ethnography, risk assessment, rural development, international development and food security (Bollig and Schulte, 1999; Ryan and Destefano, 2000; Pelletier et al., 1999; Smith et al., 2000). In the climate change adaptation and disaster management fields, analytical frameworks very similar to these have been developed and some have been applied (Jones, 2001; Lim et al., 2004; Turner et al., 2003; Schröter et al., 2005)

Participatory vulnerability assessments allow for the recognition of multiple stimuli beyond those related to climate, to include political, cultural, economic, institutional and technological forces. Furthermore, the methodologies recognize the interaction of various exposures, sensitivities and adaptive capacities over time. What is vulnerable in one period is not necessarily vulnerable (or vulnerable in the same way) in the next, and some exposures and sensitivities (e.g. those recognized as "creeping hazards" by Wisner et al., 2004) develop slowly over time. Finally, the approach recognizes that sources of exposures, sensitivities and adaptive capacities function across scales, from the individual to the national (e.g. Wisner et al.'s recognition of global scale "root causes" to local "unsafe conditions").

Fig. 3 presents a general summary of the participatory vulnerability assessment approach, based on such work as

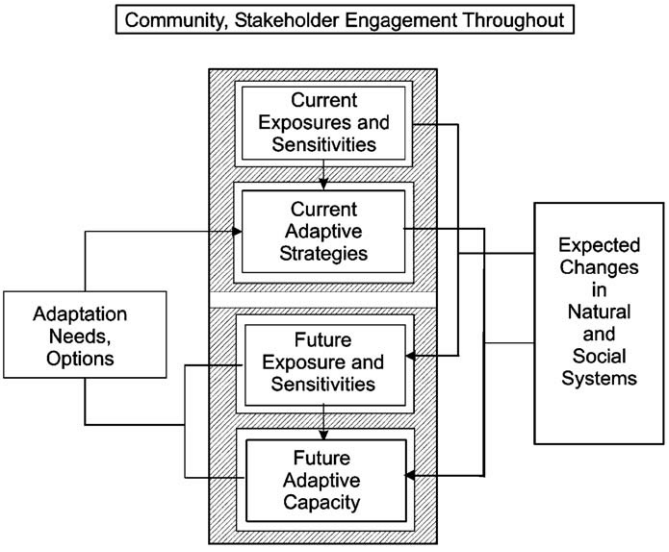

Fig. 3. Conceptual framework for vulnerability assessment and mainstreaming.

Ford and Smit (2004), Lim et al. (2004), Sutherland et al. (2005) and Vásquez-León et al. (2003). The system of interest in this case is the community, but the analysis seeks to identify the broader conditions and structures within which the community functions. The exercise requires active involvement of community stakeholders. Researchers begin with an assessment of current exposures, sensitivities and current adaptive capacity, employing ethnographic in-community methods (including such tools as semi-structured interviews, participant observation and focus groups), as well as insights from local and regional decision-makers, resource managers, scientists, published and unpublished literature, and other available sources of information. The aim of this analysis is to identify and document the conditions or risks (current and past exposures and sensitivities) that people have to deal with, and how they deal with these, including the factors and processes that constrain their choices (current and past adaptive capacity).

Once relevant conditions have been identified, and future livelihoods considered, information from other scientists, policy analysts, and decision-makers, are integrated into the analysis to identify potential future exposures and sensitivities (what conditions or risks the community may be facing) and future adaptive capacity (in what ways the community may potentially plan for or respond to these conditions) to determine future vulnerability. Opportunities to reduce future vulnerabilities are sought with community decision-makers, and representatives of other agencies with authority or influence. Experience to date has shown that the common adaptation practices involve modifying some existing resource management strategy (e.g. water conservation in the Cook Islands), livelihood enhancement initiatives (e.g. income diversification in Bangladesh), disaster preparedness plan (e.g. flood or hurricane warning and planning in coastal Vietnam), or sustainable development program (land management alternatives in central Mexico).

The goal of the methodology outlined above is not to produce a score or rating of a particular community's current or future vulnerability. Rather, the aim is to attain information on the nature of vulnerability and its components and determinants, in order to identify ways in which the adaptive capacity can be increased and exposure-sensitivities decreased. While adaptation options are evaluated in some way, the initiatives are rarely discrete stand-alone, exclusively climate change measures that are amenable to comparative scoring. Instead, adaptation initiatives tend to be incremental, modifying some existing water management strategy, disaster plan, and so on. This is commonly known as mainstreaming (Huq and Burton, 2003; Huq et al., 2003; Huq and Reid, 2004). Successful climate change adaptation and vulnerability reduction is rarely undertaken with respect to climate change alone, and vulnerability reduction appears to be most effective if undertaken in combination with other strategies and plans at various levels.

6. Conclusion

Adaptation is still a novel concept to some in the climate change field, but is has considerable history in others fields. That work has shown that adaptations in human communities are closely associated with, and reflective of, adaptive capacity and vulnerability. In particular, it has shown that vulnerability is related both to the differential exposure and sensitivity of communities to stimuli such as climate change and also to the particular adaptive capacities of those communities to deal with the effects or risks associated with the exposures. While exposures, sensitivities and adaptive capacities are evident at community or local levels, they reflect broader forces, drivers or determinants that shape or influence local level vulnerabilities.

Studies of adaptation to climate change have provided many insights but to date, have shown only moderate practical effect in reducing vulnerabilities of people to risks associated with climate change. One widely acknowledged lesson is that adaptations are rarely undertaken in response to climate change effects alone, and certainly not to climatic variables that may be of importance to decision-makers. The broader literature has also shown the utility of including decision processes in the exercise if it is aiming to affect implementation. There has been considerable scholarship in the climate change context on calculating indices of vulnerability and adaptive capacities, and on evaluating hypothetical adaptations, yet the practical applications of this work (in reducing vulnerabilities of people) are not yet readily apparent. Some success in practical implementation has been seen when measures that address climate change risks are incorporated into existing decisions structures relating to risk management, land use planning, livelihood enhancements, water and other resource management systems, development initiatives, and so on.

This movement to "mainstreaming" adaptation to climate change is consistent with the broader literature on how adaptations and adaptive capacity work. That literature also makes it clear that local initiatives, to enhance livelihoods and hence adaptive capacity, may be constrained or even nullified by broader social, economic and political forces that effectively shape local vulnerabilities. This brings the adaptation issue to the question of development and the role of local initiatives relative to transformations of geo-political–economic systems. In the climate change field, adaptations can be considered as local or community-based adjustments to deal with changing conditions within the constraints of the broader economic–social–political arrangements. Where those constraints are particularly binding, adaptation may be considered as attempting changing those broad economic–social–political structures themselves.

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