Vulnerability, Risk and Adaptation: A Conceptual Framework

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November 2003

Tyndall Centre for Climate Change Research Working Paper 38

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Tyndall Centre Working Paper No. 38
September 2003

Summary

The purpose of this paper is to present a tentative conceptual framework for studies of vulnerability and adaptation to climate variability and change, generally applicable to a wide range of contexts, systems and hazards. Social vulnerability is distinguished from biophysical vulnerability, which is broadly equivalent to the natural hazards concept of risk. The IPCC definition of vulnerability is discussed within this context, which helps us to reconcile apparently contradictory definitions of vulnerability. A concise typology of physically defined hazards is presented; the relationship between the vulnerability and adaptive capacity of a human system depends critically on the nature of the hazard faced. Adaptation by a system may be inhibited by process originating outside the system; it is therefore important to consider "external" obstacles to adaptation, and links across scales, when assessing adaptive capacity.

1 Introduction

The study of the vulnerability of human and natural systems to climate change and variability, and of their ability to adapt to changes in climate hazards, is a relatively new field of research that brings together experts from a wide range of fields, including climate science, development studies, disaster management, health, social science, policy development and economics, to name but a few areas. Researchers from these fields bring their own conceptual models to the study of vulnerability and adaptation, models which often address similar problems and processes using different language. Somehow researchers from all these different backgrounds must develop a common language so that vulnerability and adaptation research can move forward in a way that integrates these different traditions in a coherent yet flexible fashion, allowing researchers to assess vulnerability and the potential for adaptation in a wide variety of different contexts, and in a manner that is transparent to their colleagues.

The growing body of literature on vulnerability and adaptation contains a sometimes bewildering array of terms: vulnerability, sensitivity, resilience, adaptation, adaptive capacity, risk, hazard, coping range, adaptation baseline and so on (IPCC, 2001; Adger et al., 2002; Burton et al., 2002). The relationships between these terms are often unclear, and the same term may have different meanings when used in different contexts and by different authors. Researchers from the natural hazards field tend to focus on the concept of risk, while those from the social sciences and climate change field often prefer to talk in terms of vulnerability (Downing *et al*., 2001; Allen, 2003). Social scientists and climate scientists often mean different things when they use the term "vulnerability"; whereas social scientists tend to view vulnerability as representing the set of socio-economic factors that determine people's ability to cope with stress or change (Allen, 2003), climate scientists often view vulnerability in terms of the likelihood of occurrence and impacts of weather and climate related events (Nicholls *et al*., 1999).

The aim of this paper is to present a conceptual framework that may be applied consistently to studies of vulnerability and adaptation in a wide range of contexts by researchers with different backgrounds, concerned with the impacts of and responses to climate variability and change within human systems. The intention is not to redefine terms and introduce an alternative array of equally bewildering terms (although one new term and qualifying adjectives for existing terms are tentatively suggested). The aim is rather to explore the concepts of vulnerability, risk and adaptation as they are currently applied, and to attempt to clarify the relationships between them. Such clarification may be achieved through practices as simple as the application of an adjective; the confusion arising from different usages of the term "vulnerability" may be largely overcome by differentiating between "social vulnerability" and "biophysical vulnerability", terms that are already commonly used by some members of the research community.

The paper concentrates on the relationships between biophysical vulnerability, social vulnerability, risk, adaptive capacity and adaptation. The concept of vulnerability is discussed, and the differences between biophysical and social vulnerability are summarized. The IPCC definition of vulnerability is examined, and related to the concepts of social and biophysical vulnerability. Definitions of risk are then examined, and related to the concepts of vulnerability and hazard. The concept of adaptive capacity is explored at some length, and emphasis is placed on the hazard-specific nature of adaptive capacity and how this mediates its relationship with vulnerability. A concise hazard typology is presented, and the implications of the different timescales associated with different hazards are addressed in terms of the adaptation process. The concepts of current, future, actual and potential vulnerability are elaborated as a basis for the quantification of vulnerability and adaptive capacity where this is desirable, for example in integrated assessment models. Finally the relationship between adaptive capacity and actual adaptation is addressed, and concerns about the potential misuse of the concept of adaptive capacity are presented. The concept of adaptation likelihood is tentatively suggested as a means of countering any attempt to use "capacity building" as a political lever to divert attention away from the large-scale structural factors that often cause or exacerbate the vulnerability of groups who have no control over such factors.

2 Biophysical versus social vulnerability

Political scientists with a definition are like dogs with a bone: they will continue to gnaw at it while ignoring more nutritious alternatives (Grant, 2000).

2.1 Biophysical and social vulnerability

There are many different definitions of vulnerability, and it is not the purpose of this paper to review them all. For a summary of definitions of and approaches to vulnerability the reader is directed to Adger, (1999). Nonetheless, it is essential to stress that we can only talk meaningfully about the vulnerability *of a specified system to a specified hazard or range of hazards*. The term *hazard* is used throughout this paper to refer specifically to physical manifestations of climatic variability or change, such as droughts, floods, storms, episodes of heavy rainfall, long-term changes in the mean values of climatic variables, potential future shifts in climatic regimes and so on. Climate hazards may be defined in terms of absolute values or departures from the mean of variables such as rainfall, temperature, wind speed, or water level, perhaps combined with factors such as speed of onset, duration and spatial extent. Hazards are also referred to as *climate events*. Crucially, hazards as described in this paper are purely physically defined. A disaster as measured in human terms (lives lost, people affected, economic losses) is therefore the *outcome* of a hazard, mediated by the properties of the human system that is exposed to and affected by the hazard. Of the phenomena listed above, floods are particularly problematic, as their magnitude is mediated by anthropogenic factors such as river engineering and land use. A flood associated with a heavy rainfall event may be more usefully viewed as a primary impact or outcome of that rainfall event, just as coastal floods are often the outcome of storm surges. In these cases it is the rainfall event or storm surge that constitute the principal hazard - whether or not we should include floods in our list of hazards is debatable. Hazards are discussed in more detail in Sections 3 and 4.

Definitions of vulnerability in the climate change related literature tend to fall into two categories, viewing vulnerability either (i) in terms of the amount of (potential) damage caused to a system by a particular climate-related event or hazard (Jones and Boer, 2003), or (ii) as a state that exists within a system before it encounters a hazard event (Allen, 2003). The former view has arisen from an approach based on assessments of hazards and their impacts, in which the role of human systems in mediating the outcomes of hazard events is downplayed or neglected. Climate change impacts studies have typically examined factors such as increases in the number of people at risk of flooding based on projections of sea level rise (e.g. Nicholls *et al*., 1999), and have thus focused on human *exposure* to hazard rather than on the ability of people to cope with hazards once they occur. The hazards and impacts approach typically views the vulnerability of a human system as determined by the nature of the physical hazard(s) to which it is exposed, the likelihood or frequency of occurrence of the hazard(s), the extent of human exposure to hazard, and the system's *sensitivity* to the impacts of the hazard(s). This view is apparent in the principal definition of vulnerability in the IPCC Third Assessment Report (TAR) (IPCC, 2001a), discussed in more detail below. This combined vulnerability, a function of hazard, exposure and sensitivity, may be referred to as *physical* or *biophysical vulnerability*. The term "biophysical" will be used here, as it suggests both a physical component associated with the nature of the hazard and its first-order physical impacts, and a biological or social component associated with the properties of the affected system that act to amplify or reduce the damage resulting from these first-order impacts. Biophysical vulnerability is concerned with the ultimate impacts of a hazard event, and is often viewed in terms of the amount of damage experienced by a system as a result of an encounter with a hazard. Jones and Boer (2003) are therefore referring to biophysical vulnerability when they state that "Vulnerability is measured by indicators such as monetary cost, human mortality, production costs, [or] ecosystem damage…" These are indicators of *outcome* rather than indicators of the state of a system prior to the occurrence of a hazard event.

Conversely, the view of vulnerability as a state (i.e. as a variable describing the internal state of a system) has arisen from studies of the structural factors that make human societies and communities susceptible to damage from external hazards (Allen, 2003). In this formulation, vulnerability is something that exists within systems independently of external hazards. For many human systems, vulnerability viewed as an inherent property of a system arising from its internal characteristics may be termed "social vulnerability" (Adger, 1999; Adger and Kelly, 1999). For vulnerability arising purely from the inherent properties of non-human systems or systems for which the term "social" is not appropriate the term "inherent vulnerability" might be used. Social vulnerability is determined by factors such as poverty and inequality, marginalisation, food entitlements, access to insurance, and housing quality (Blaikie et al., 1994; Adger and Kelly, 1999; Cross, 2001). It is social vulnerability that has been the primary focus of field research and vulnerability mapping projects, which are generally concerned with identifying the most vulnerable members of society, and examining variations in vulnerability between or within geographical units that may experience similar hazards (Downing and Patwardhan, 2003). In this formulation, it is the interaction of hazard with social vulnerability that produces an outcome, generally measured in terms of physical or economic damage or human mortality and morbidity (Brooks and Adger, 2003). Hence social vulnerability may be viewed as one of the determinants of biophysical vulnerability.

The nature of social vulnerability will depend on the nature of the hazard to which the human system in question is exposed: although social vulnerability is not a function of hazard severity or probability of occurence, certain properties of a system will make it more vulnerable to certain types of hazard than to others. For example, quality of housing will be an important determinant of a community's (social) vulnerability to a flood or windstorm, but is less likely to influence its vulnerability to drought. So, although social vulnerability is not a function of hazard, it is, to a certain extent at least, hazard specific – we must still ask the question "vulnerability of who or what to what?" Nonetheless, certain factors such as poverty, inequality, health, access to resources and social status are likely to determine the vulnerability of communities and individuals to a range of different hazards (including non-climate hazards). We may view such factors as "generic" determinants of social vulnerability, and others such as the situation of dwellings in relation to river flood plains or low-lying coastal areas as determinants that are "specific" to particular hazards, in this example, flooding and storm surges.

In summary, biophysical vulnerability is a function of the frequency and severity (or probability of occurrence) of a given type of hazard, while social or inherent vulnerability is not. A hazard may cause no damage if it occurs in an unpopulated area or in a region where human systems are well adapted to cope with it. Where biophysical vulnerability is viewed in terms of outcome (damage resulting from the interaction of hazard and social vulnerability), a system that sustained no net damage from a hazard might be interpreted *post hoc* as being "invulnerable" to that hazard.

In this paper the term "social vulnerability" is used in a broad sense to describe all the factors that determine the outcome of a hazard event of a given nature and severity. Social vulnerability encompasses all those properties of a system independent of the hazard(s) to which it is exposed, that mediate the outcome of a hazard event. This may include environmental variables and measures of exposure. For example the vulnerability of a country to a given hazard occurring over its national territory will be a function of the percentage of the population living in the area affected by the hazard, but also of the extent to which individuals and sub-national scale systems within this area are exposed to its first-order impacts. Exposure and the state of the environment within a system will be socially determined to a large extent. Exposure will depend on where populations choose to (or are forced to) live, and how they construct their settlements, communities and livelihoods. Environmental variables will vary in response to human activity, as populations exploit resources and manage the environment for their benefit in the short or long term. Social vulnerability as described here therefore encompasses elements of the physical environment as they relate to human systems, including factors such as topography and river engineering schemes (which mediate the outcome of flood events), and groundwater reserves (which may mediate the outcome of a meteorological drought by enabling people to compensate for lack of rain through irrigation).

2.2 IPCC definitions of vulnerability

The IPCC Third Assessment Report (TAR) describes vulnerability as

> "The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity." (IPCC, 2001, p. 995) (IPCC Def. 1)

Exposure is defined in the same report as "The nature and degree to which a system is exposed to significant climatic variations." Sensitivity is "the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea level rise)." Adaptive capacity is "The ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences."

The above definition may be compared with that given in Chapter 18 of the TAR, cited from Smit *et al.* (1999), in which vulnerability is described as the "degree to which a system is susceptible to injury, damage, or harm (one part - the problematic or detrimental part - of sensitivity)" (IPCC Def. 2). Sensitivity is in turn described as the "Degree to which a system is affected by or responsive to climate stimuli" (IPCC, 2001, p. 894).

The two IPCC definitions above are very different, and are not consistent. IPCC Def. 1 views the vulnerability of a system as a function of its sensitivity, while Definition 2 views vulnerability as a subset of sensitivity. Vulnerability in IPCC Def. 2 is therefore a subset of one of the determinants of vulnerability as defined in IPCC Def. 1, making the two definitions contradictory, provided they are assumed to be describing the same type of vulnerability.

This contradiction further illustrates the principal disagreement over the definition of vulnerability within the climate change research community, namely whether vulnerability is determined purely by the internal characteristics of a system, or whether it also depends on the likelihood that a system will encounter a particular hazard. In other words, whether we use the term "vulnerability" to mean biophysical or social vulnerability. IPCC Def. 1 clearly refers to biophysical vulnerability, with "sensitivity" (or at least "the detrimental part of sensitivity") in IPCC Def. 1 playing an equivalent role to social vulnerability where human systems are concerned, while IPCC Def. 2 refers only to social or inherent vulnerability. If we view Def. 1 as a definition of biophysical vulnerability and Def. 2 as a definition of social vulnerability, the conflict is resolved. It would therefore be prudent for researchers in future to avoid using the word "vulnerability" without any further clarification, and to specify to which type of vulnerability they are referring. Such a recommendation does not require terms to be redefined, and has few or no implications for the way in which analyses of either type of vulnerability are carried out, but will prevent much of the confusion that has characterized the vulnerability debate to date.

3 Vulnerability and risk

Biophysical vulnerability, as implicitly described in IPCC Def. 1, has much in common with the concept of risk as elaborated in the natural hazards literature. A number of definitions of risk from a variety of different sources is presented in Table 1, along with associated definitions of hazard where these are also given in the source material.

The definitions in Table 1 are probabilistic in nature, relating either to (i) the probability of occurrence of a hazard that acts to trigger a disaster or series of events with an undesirable outcome, or (ii) the probability of a disaster or outcome, combining the probability of the hazard event with a consideration of the likely consequences of the hazard. The various definitions generally present hazard in terms compatible with the view of hazard elaborated earlier in this paper, although in certain definitions there is some ambiguity as to whether hazard represents a trigger event or the outcome of such an event. Jones and Boer (2003) define hazard explicitly in physical terms. Stenchion (1997) and UNDHA (1992) implicitly define hazard in a similar manner, as an event that might precipitate a disaster but which does not itself constitute a disaster. Where vulnerability is included in the definition of risk, it is viewed as distinct from hazard: it is therefore social vulnerability that is being referred to. Risk defined as a function of hazard and social vulnerability is compatible with risk defined as probability x consequence, and also with risk defined in terms of outcome. The probability of an outcome will depend on the probability of occurrence of a hazard and on the social vulnerability of the exposed system, which will determine the consequence of the hazard.

The ambiguity as to whether it is the probability of occurrence of a hazard, or the probability of a particular outcome that is being referred to is addressed by Sarewitz *et al*. (2003). They define *event risk* as the "risk of occurrence of any particular hazard or extreme event" and *outcome risk* as "the risk of a particular outcome". They state that outcome risk "integrates both the characteristics of a system and the chance of the occurrence of an event that jointly results in losses." Sarewitz *et al*. (2003) are referring to social or inherent vulnerability when they "use the word 'vulnerability' to describe inherent characteristics of a system that create the potential for harm but are independent of the probabilistic *risk of occurrence* ("event risk") of any particular hazard or extreme event."

Outcome risk may therefore be viewed as a function of event risk and inherent or social vulnerability, a formulation broadly consistent with the definitions of risk in Table 1, as long as we acknowledge the ambiguities in the definitions of hazard. This definition of outcome risk is also broadly equivalent to the definition of biophysical vulnerability presented in Section 2.1. Event risk as described by Sarewitz *et al*.

(2003) is associated with hazard as defined in physical terms, a view consistent with the concept of hazard as outlined in Section 2.1 and by Jones and Boer (2003).

Author(s)	Risk definition
Smith, 1996 (p5)	Probability x loss (probability of a specific hazard occurrence) *Hazard = potential threat*
IPCC, 2001 (p21)	Function of probability and magnitude of different impacts
Morgan and Henrion, 1990 (p1)/Random House, 1966	"Risk involves an 'exposure to a chance injury or loss'"
Adams, 1995 (p8)	"a compound measure combining the probability and magnitude of an adverse affect"
Jones and Boer, 2003; (also Helm, 1996)	Probability x consequence *Hazard: an event with the potential to cause harm, e.g. tropical cyclones, droughts, floods, or conditions leading to an outbreak of disease-causing organisms.*
Downing et al., 2001	Expected losses (of lives, persons injured, property damaged, and economic activity disrupted) due to a particular hazard for a given area and reference period *Hazard: a threatening event, or the probability of occurrence of a potentially damaging phenomenon within a given time period and area.*
Downing et al., 2001	Probability of hazard occurrence *Hazard = potential threat to humans and their welfare*
Crichton, 1999	"Risk" is the probability of a loss, and depends on three elements, hazard, vulnerability and exposure."
Stenchion, 1997	"Risk might be defined simply as the probability of occurrence of an undesired event [but might] be better described as the probability of a hazard contributing to a potential disaster…importantly, it involves consideration of vulnerability to the hazard."
UNDHA, 1992	"Expected losses (of lives, persons injured, property damaged, and economic activity disrupted) due to a particular hazard for a given area and reference period. Based on mathematical calculations, risk is the product of hazard and vulnerability."

Table 1*: Definitions of risk and hazard. The definitions of Chrichton (1999), Stenchion (1997) and UNDHA (1992) are taken from a similar table in Kelman (2003).*

The principal difference between the natural hazards risk-based approach and the IPCC biophysical vulnerability approach is that risk is generally described in terms of probability, whereas the IPCC and the climate change community in general tend to describe (biophysical) vulnerability simply as a function of certain variables. Nonetheless, the determinants of both biophysical vulnerability and risk are essentially the same - hazard and social vulnerability.

The natural hazards community, which emphasizes risk, and the climate change community, which emphasizes vulnerability, are essentially examining the same processes. However, this has not always been immediately apparent, due to differences in terminology. Both are ultimately interested in the physical hazards that threaten human systems, and in the outcomes of such hazards as mediated by the properties of those systems, described variously in terms of vulnerability, sensitivity, resilience, coping ability and so on. The separation of vulnerability into social and biophysical vulnerability enables us to appreciate the compatibility of the risk-based and vulnerability-based approaches. The concept of biophysical vulnerability addresses the same issues as the concept of risk or, adopting the more precise terminology of Sarewitz *et al*. (2003), outcome risk. Both [outcome] risk and biophysical vulnerability are functions of hazard and social vulnerability, and we may view social vulnerability as equivalent to sensitivity when we are concerned with human systems. The essential equivalence of [outcome] risk and biophysical vulnerability as described above is further illustrated by a report from the International Strategy for Disaster Reduction which separates "risk factors" into two components: "hazard (determines geographical location, intensity and probability)" and "vulnerability/capacities (determines susceptibilities and capacities)" (United Nations, 2002, p.66).

The integration of the risk-based and vulnerability-based approaches is desirable if we are to address the numerous threats that human systems will face in the future as a result of climate variability and change, and also from non-climate hazards. As stated by Kasperson et al. (2001), "What is essential is to assess vulnerability as an integral part of the causal chain of risk and to appreciate that altering vulnerability is one effective risk-management strategy."

Placing social or inherent vulnerability within the context of risk, and viewing biophysical vulnerability and risk as broadly equivalent, should go some way towards reducing the confusion associated with definitions of vulnerability and facilitating better communication between researchers with different backgrounds, therefore improving the prospects of managing the threats posed by climate variability and change. Indeed, we could institute a new convention regarding terminology, in which we speak of risk instead of biophysical vulnerability, and use the word "vulnerability" only to refer to social vulnerability. However, Grant (2000) follows his statement about political scientists with the following sound advice: "Let us not let terminology stand in the way of our exploration of process." We should not distract ourselves from the very real need to manage risk and reduce vulnerability with arguments over which formulation of vulnerability is "best". Indeed, it is hoped that the above discussion has demonstrated that we need only be more careful and concise with our existing definitions, rather than redefine terms such as vulnerability and risk. While it is recognised that different contexts require different approaches, it is essential that researchers working in the same field use a common language.

4 Adaptive capacity, adaptation and vulnerability

The above discussion has gone some way towards developing a conceptual framework of vulnerability and risk, based on the distinction between social and biophysical vulnerability, and on the equivalence of biophysical vulnerability and risk. This distinction helps us to make sense of the apparently contradictory definitions in the IPCC TAR (IPCC, 2001), by associating hazard with climate variation, sensitivity with social vulnerability, and vulnerability as defined in IPCC Def. 1 with biophysical vulnerability or risk. However, we have not yet addressed the issue of adaptive capacity, and its relationship to social and biophysical vulnerability.

Many definitions of adaptive capacity exist (e.g. IPCC, 2001; Burton et al., 2002; Adger et al., 2003); broadly speaking it may be described as the ability or capacity of a system to modify or change its characteristics or behaviour so as to cope better with existing or anticipated external stresses. We may view reductions in social vulnerability as arising from the realization of adaptive capacity as adaptation. The term adaptation is used here to mean *adjustments in a system's behaviour and characteristics that enhance its ability to cope with external stresses*. Given constant levels of hazard over time, adaptation will allow a system to reduce the risk associated with these hazards by reducing its social vulnerability. Faced with increased hazard, a system may maintain current levels of risk through such adaptation; reductions in risk in the face of increased hazard will require a greater adaptation effort. If hazards increase dramatically in frequency or severity, a human system may face greater risk despite reduction in social vulnerability achieved through the implementation of adaptation strategies.

The direct effect of adaptation is therefore to reduce social vulnerability. Whether or not this translates into a reduction in biophysical vulnerability or risk will depend on the evolution of hazard. In the case of anthropogenic greenhouse warming and any associated changes in climate, the only certain way of reducing risk is therefore via a combination of adaptation and mitigation strategies, the purpose of the latter being to reduce hazards. In the following discussion on adaptive capacity and adaptation, the term vulnerability will therefore be used to refer to *social vulnerability*, unless otherwise stated. Where the text refers to reductions in vulnerability as a result of adaptation, this should be interpreted as social vulnerability, and by extension to biophysical vulnerability *only under conditions of constant hazard*.

4.1 Vulnerability and adaptation as hazard-specific

In IPCC Def. 1, biophysical vulnerability is a function of adaptive capacity, which is viewed as distinct from sensitivity, which we may view in turn as being broadly equivalent to social vulnerability. Given the broad equivalence of biophysical vulnerability and risk (Section 3), IPCC Def. 1 suggests that if a system has a high capacity to adapt, it is less "at risk". However, this definition fails to place risk, vulnerability (both biophysical and social) and adaptive capacity in a hazard-specific context.

It makes little sense to talk about a system's vulnerability and adaptive capacity without specifying the hazard to which it is vulnerable and to which it must adapt. Once we accept that risk, vulnerability and adaptive capacity are hazard-specific, we must then recognise that there are many different kinds of climate hazard, operating over a variety of different timescales and requiring a variety of adaptation responses. A system may have the capacity to adapt to certain types of hazard, but not to others.

Three broad categories of hazard may be identified:

Category 1: Discrete recurrent hazards, as in the case of transient phenomena such as storms, droughts and extreme rainfall events.

Category 2: Continuous hazards, for example increases in mean temperatures or decreases in mean rainfall occurring over many years or decades (such as anthropogenic greenhouse warming or desiccation such as that experienced in the Sahel over the final decades of the 20th century (Hulme, 1996; Adger and Brooks, 2003).

Category 3: Discrete singular hazards, for example shifts in climatic regimes associated with changes in ocean circulation; the palaeoclimatic record provides many examples of abrupt climate change events associated with the onset of new climatic conditions that prevailed for centuries or millennia (Roberts, 1998; Cullen *et al*., 2000; Adger and Brooks, 2003).

Adaptation does not occur instantaneously; a system requires time to realise its adaptive capacity as adaptation. Adaptive capacity represents *potential* rather than actual adaptation. A high level of adaptive capacity therefore only reduces a system's vulnerability to hazards occurring in the future (allowing the system time to adapt in an anticipatory manner) or to hazards that involve slow change over relatively long periods, to which the system can adapt reactively. In other words, adaptive capacity is a determinant of vulnerability to Category 2 hazards and also of the future vulnerability to *anticipated* Category 1 and 3 hazards. The damage to a system resulting from a discrete hazard event such as a storm or flood occurring tomorrow would not be a function of the system's ability to pursue future adaptation strategies – it is existing adaptations resulting from the past realization of adaptive capacity that determine current levels of vulnerability. The likelihood of a system adapting responsively to (as opposed to coping with) a sudden short-lived event such as a hurricane is negligible.

However, a system's vulnerability to more gradual, longer-term change will be a function of it's ability to adapt incrementally and responsively, and its vulnerability to discrete hazards occurring in the future will be a function of its ability to anticipate and pre-empt those hazards via appropriate planned adaptation strategies. The rate at which *risk* (or biophysical vulnerability) associated with a particular type of hazard is reduced (or increased) will depend on the timescales associated with the implementation of adaptation measures (i.e. the realisation of adaptive capacity as adaptation) and also on the timescales associated with the evolution or occurrence of the hazard in question (in the case of global-scale anthropogenic climate change the latter will be influenced by global development pathways and the extent to which mitigation is pursued). In other words, we must ask ourselves whether a system is likely to implement the necessary adaptation measures in the time available to it in order to reduce risk to a subjectively defined acceptable level.

For example, global mean sea level is expected to rise by a maximum of around 45 cm by 2050 (Sear et al., 2001). While many countries are *currently* vulnerable to a 45 cm sea level rise (assuming no further adaptation were to occur over the next half-century), for this particular threat we are concerned with future vulnerability, perhaps assessed in terms of the ability to cope with a given annual or decadal rise in sea level up until the middle of the twenty first century. The risk posed to a country or coastal zone by sea level rise will depend on the rate at which it occurs, the system or region's existing vulnerability, and the rate at which the system can adapt (c.f. IPCC Def. 1). Existing (social) vulnerability is important as it constitutes the "baseline" from which any reduction of vulnerability to "acceptable" levels via adaptation must take place. Risk assessments for sea level rise typically examine the risk associated with a given increase in sea level assuming current levels of social vulnerability, perhaps modulated by changes in population density (Nicholls et al., 1999; Parry et al., 2001). A comprehensive assessment of risk would examine the likelihood of a specific rate of sea level rise over a given period (hazard), and the potential or likely evolution of a system's vulnerability to that rise based on *current vulnerability* and the *potential or likely amount of adaptation* over that period.

4.2 Adaptive capacity and current and future vulnerability

Another way of addressing the important issue of timescale is to distinguish between current and future vulnerability. Current vulnerability, determined by past adaptation and the current availability of coping options, provides a baseline from which a system's future vulnerability will evolve. This evolution will be mediated by the system's adaptive capacity and the extent to which this capacity is realised as adaptation. At any given time, we may view a system as exhibiting a certain degree of vulnerability to a specified hazard, and as having a certain ability or potential to adapt so as to reduce its vulnerability to that hazard within any given time frame, constrained or modulated by a range of external factors.

If the hazard in question is a particular type of discrete, transient, extreme climatic event, we may speak in terms of the system's *current vulnerability*, a "snapshot" which determines the extent to which it would be damaged if the event in question occurred immediately. We may also speak of the system's *potential vulnerability*, or the vulnerability it would have at a specified point in the future to a specific hazard as a result of realizing all its current adaptive capacity through anticipatory adaptation. If we define adaptive capacity, α, as the potential adaptation per unit time based on existing conditions, and adaptation as representing a reduction in vulnerability, then potential vulnerability at time t, assessed at time t=0, may be represented by the following expression:

$$V_p^t = V_0 - \alpha_0 t \quad \text{………Equation 1}$$

where V_0 is current vulnerability (at t=0) and α_0 represents current adaptive capacity.

If we assume that adaptation is a function of adaptive capacity only, in other words that all a system's adaptive capacity is realised as adaptation, we may represent the *actual vulnerability* of a system at time t as

$$V^t = V_0 - \int \alpha dt \text{ ....Equation 2}$$

where α represents dynamic adaptive capacity, acknowledging the fact that adaptive capacity will fluctuate over time as the environmental, political, social and economic factors that determine adaptive capacity change. Adaptive capacity may also be reduced by the impacts of the very hazards that a system must adapt to.

The above mathematical formulations allow vulnerability and adaptation studies to be put on a more quantitative footing where this is deemed to be desirable, for example in terms of integrated assessments involving modelling components, or where quantification is useful in order to assess the success or failure of adaptation strategies. Differences in social vulnerability resulting from different development pathways might be assessed by running models with a suite of different socio-economic scenarios under conditions of constant hazard. Outcomes measured in terms of mortality and morbidity or economic damage could then be used to assess the impacts of different modes of development on social vulnerability (assuming each socio-economic scenario is associated with the same hazard(s)). Of course vulnerability is also influenced by hazard events through a variety of feedback processes such as the destruction of resources and the exacerbation of poverty and inequality by climate-related disasters. Such processes should be accounted for in modelling studies if they are to be of any value.

5 Systems, scales and the constituents of adaptive capacity

The above discussion focuses on the relationship between adaptive capacity and vulnerability, viewing the former in the broadest possible terms. However, if we wish to assess existing adaptive capacity, we must understand how it is constituted, and how it is translated into adaptation. In other words, we must understand the adaptation process. This process will depend on the nature of the systems that are adapting; for example, the processes via which a household or local community adapts to changes in climatic conditions will be very different from those via which a nation state adapts. In the former case, adaptation will be determined by factors such as health and education, access to information, financial and natural resources, the existence of social networks, and the presence or absence of conflict. In the latter case, adaptation will depend on relationships between the government, the private sector and civil society, the regulatory environment and the effectiveness of state institutions, national wealth, economic autonomy and so on.

The factors that determine whether or not adaptation occurs will operate at a variety of scales, and will depend on how the "system" being assessed is defined. Different systems are characterized by different scales (for example spatial scales or scales representing interactions between individuals, groups or institutions), and different systems will interact with one other; the processes operating within one system may directly or indirectly affect another system. Examples of such cross-scale linkages include links between the local and national scale; market intervention at the national or international level may affect the price of a commodity produced by a household or community, with dramatic consequences for the latter's economic status and resulting ability to invest in household or community level adaptation to a hazard such as drought.

We therefore cannot view systems as closed, nor can we assess a system's ability to adapt without considering the role of obstacles to adaptation that might be determined by processes operating outside of the system in question. Indeed, we might even divide the factors that determine whether or not adaptation occurs, and to what extent, into "endogenous" and "exogenous" factors. In practice this may represent an unnecessary complication, given the complex interactions between systems and across scales. However, it is a useful conceptual division, as it reminds us that in order to facilitate adaptation, we must address not only those processes operating at the sub-system scale, but also the wider social, economic, political and environmental contexts within which the system of interest is embedded. There is currently a tendency for vulnerability and poverty to be addressed solely in terms of "endogenous" factors - the characteristics and behaviour of vulnerable and poor populations - with little regard to the wider economic and geopolitical context that often causes or exacerbates poverty and vulnerability (O'Brien and Leichenko, 2000; Pelling and Uitto, 2001; Singh, 2002). This approach, evident in the current vogue for "capacity building", may be interpreted as being to a large extent a result of the desire of researchers and policy makers to avoid challenging the powerful political and economic vested interests that determine the nature of the adaptation context, and of the view that it is either undesirable or impossible to question the fundamental geopolitical and economic contexts within which adaptation must be carried out. There is a danger that the concepts of adaptive capacity and capacity building will be employed in the same manner as the concept of social capital has arguably been employed by bodies such as the World Bank, as a justification for inaction regarding the large-scale structural causes of poverty, inequality and vulnerability ("macro-relations of power" – Fine, 1999) by emphasizing micro-scale processes as the key to sustainable development. This is not to say that micro-scale processes are not important, simply that they are not necessarily sufficient for successful adaptation to occur. For example, migration from rural areas to vulnerable coastal towns will not be reversed by investment in export agriculture at a sub-national scale if the resulting produce is worthless because of trade barriers, EU and US agricultural subsidies, and global price-fixing monopolies. International financial institutions might influence a country's adaptive capacity by persuading that country to alter its institutional and economic infrastructure, and divest itself of certain assets or resources (such as food reserves). Those same institutions might then influence the extent to which the country in question is able to realize its existing adaptive capacity by influencing national economic policy in order to achieve outcomes acceptable within the context of the dominant economic ideology. Other supra-national bodies, international agreements and inter-state conflicts may also influence the likelihood of adaptation by determining the country's access to global markets and technology.

Furthermore, theories of adaptive capacity must not fall into the same trap of certain theories of social capital, and "neglect power and conflict" (Fine, 1999) within human systems and societies. At the system-scale, whether or not adaptive capacity is realised is sometimes viewed as dependent on "political will", a problematic term that tends to view the complex institutions and processes of governance and state-society interaction as an impenetrable "black box" rather than attempt to explain action or inaction by a society (O'Riordan et al., 1998; Adger et al., 2002). The factors that determine a society's "political will" should themselves be subject to investigation if we are to understand the adaptation process.

In summary, the extent to which adaptation occurs will be decided by processes operating at a range of scales, and some of these will be different from the scale at which the system of interest is defined. The view of adaptive capacity as something "inherent" in a system is likely to lead to an emphasis on processes operating at the system and sub-system scale, and to a neglect of larger-scale processes, an outcome that will be convenient for certain ideologically-based groups and institutions. The issue of scale leads us to think more carefully about our definition of adaptive capacity: will a system with high adaptive capacity automatically adapt? In other words, is adaptive capacity "self-realising"? For this to be the case, the definition of adaptive capacity must encompass all the processes that determine whether or not adaptation takes place, and to what extent, including those associated with different scales and systems, representing the environmental, economic and geopolitical context in which the system of interest is embedded. Perhaps a more appropriate term would be *adaptation likelihood*. While use of the term "adaptive capacity" often leads to debate as to where "inherent" capacity ends and external obstacles to adaptation begin, the term “adaptation likelihood” more naturally encompasses determinants at different scales.

However, there is resistance to the introduction of new terms into what is already a terminology-heavy field. It is left to the reader to decide whether they will continue to use the term “adaptive capacity”, or adopt the term “adaptation likelihood” in future analysis and discussion. If the former approach is adopted, the importance of definition is once again emphasized. Just as communications should state whether the subject of discussion is biophysical vulnerability (risk) or social vulnerability, so they should also specify whether the term adaptive capacity is used to mean inherent capacity determined at and below the system scale, or all the factors that influence the adaptation process, including external obstacles that may frustrate the adaptation process even if those undertaking it have both the willingness to adapt and access to the necessary resources.

The above considerations of systems and scales have important implications for the quantification and modelling of adaptive capacity. Equations 1 and 2 above are based on a definition of adaptive capacity including determinants at different scales (adaptation likelihood); V^t diverges from V_p^t only as a result of changes in α occurring in response to *changes* in environmental, political, social and economic conditions. If these conditions remained constant V_p^t and V^t would be equivalent. This would not be the case if α represented determinants at and below the system scale only; even if prevailing environmental, political and socio-economic conditions remained constant, V_p^t would deviate from V^t by an amount determined by the extent to which the realisation of adaptive capacity was impeded by external factors, and Equation 2 would require an additional term to represent this effect.

6 Conclusions

This paper has developed a conceptual framework of risk, vulnerability and adaptive capacity that synthesises a variety of approaches. By distinguishing between social and biophysical vulnerability we can resolve the apparent conflict between different formulations of vulnerability in the climate change literature. By acknowledging the broad equivalence between biophysical vulnerability and the natural hazards concept of risk, we can place the study of social vulnerability within a risk management framework. Within this framework, the risk posed to a human system by a particular type of hazard will be a function of the severity and probability of occurrence of the hazard and the way in which its consequences are likely to be mediated by the social vulnerability of the human system in question. Risk may be quantified in terms of outcome, for example in terms human mortality and morbidity and/or economic losses. This may be *post hoc* for a particular event or set of events, or in terms of likely or anticipated outcome. Alternatively, risk may be assessed probabilistically as the likelihood of a particular outcome. Social vulnerability, on the other hand, is more likely to be measured in terms of predictive variables representing factors such as economic well being, health and education status, preparedness and coping ability with respect to particular hazards and so on.

The adaptive capacity of a human system represents the potential of the system to reduce its social vulnerability and thus to minimise the risk associated with a given hazard. While many factors will determine a system’s capacity to adapt to a variety of existing or anticipated hazards, other aspects of adaptive capacity will be hazard-specific. The nature of the hazards faced by a human system, and the timescales associated with them, will determine the nature of its adaptive capacity and of appropriate adaptation strategies.

Future studies of vulnerability, adaptive capacity and adaptation will be of greater utility to the wider research community if those undertaking them ask themselves the following questions at the outset:

1. Are we principally concerned with biophysical or social vulnerability?
2. What the principal hazards with which we are concerned and how do they affect the adaptation process and the relationship between vulnerability and adaptive capacity?
3. Are we defining adaptive capacity at the system and sub-system level only, or does our definition include the "exogenous" factors that facilitate or inhibit the realisation of sub-system capacity?

These simple steps should go some way towards ensuring greater synergy between actual vulnerability assessments and more theoretical work, and enhancing communication between researchers from different backgrounds.

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