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DEVELOPING CREDIBLE VULNERABILITY INDICATORS FOR CLIMATE ADAPTATION POLICY ASSESSMENT

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Abstract. We address the issue of how to develop credible indicators of vulnerability to climate change that can be used to guide the development of adaptation policies. We compare the indicators and measures that five past national-level studies have used and examine how and why their approaches have differed. Other relevant indicator studies of social facets of society as well as vulnerability studies at sub-national level are also examined for lessons regarding best practice. We find that the five studies generally emphasise descriptive measures by aggregating environmental and social conditions. However, they vary greatly both in the types of indicators and measures used and differ substantially in their identification of the most vulnerable countries. Further analysis of scientific approaches underlying indicator selection suggests that the policy relevance of national-level indicators can be enhanced by capturing the processes that shape vulnerability rather than trying to aggregate the state itself. Such a focus can guide the selection of indicators that are representative even when vulnerability varies over time or space. We find that conceptualisation regarding how specific factors and processes influencing vulnerability interact is neither given sufficient consideration nor are assumptions transparently defined in previous studies. Verification has been neglected, yet this process is important both to assess the credibility of any set of measures and to improve our understanding of vulnerability. A fundamental lesson that emerges is the need to enhance our understanding of the causes of vulnerability in order to develop indicators that can effectively aid policy development.

Keywords: adaptation, climate change, climate policy, coping, vulnerability, vulnerability indicators

1. Introduction

There is a long history of vulnerability studies concerned with identifying those population groups that are most likely to experience the negative effects of drought and other natural hazards as well as the adverse consequences of conflict or other social, economic or political forces (Anderson and Woodrow 1991; Blaikie et al. 1994; Cutter et al. 2003). One aim of this work has been the effective targeting of preventative measures and disaster relief, such as through early warning systems (Lonergan et al. 1999). Reflecting the extent of the causal factors and driving forces, the spatial scale of these studies has tended to be local to regional. Recently, the recognition of anthropogenic climate change as a global environmental threat has resulted in many studies of the potential impact of this problem

in different parts of the world, often using vulnerability as a framing device. Moreover, there has been an increasing requirement in recent years for assessments of vulnerability to climate change at the national to global scale (McCarthy et al. 2001). In this paper, we address the problem defined by Kelly and Adger (2000) and Burton et al. (2002) that the emerging emphasis on policy development and the identification of adaptation options requires new types of vulnerability studies.

We focus on quantitative estimates of vulnerability at the national level for use in continent-wide or global comparison, calls for which have been largely policy driven. Objective comparison of levels of vulnerability between countries is needed as a way of allocating priorities for funding and intervention, for example, in the context of the Adaptation Fund set up under the United Nations Framework Convention on Climate Change (Klein 2003). To support this effort, there is a need for quantitative measures of relative vulnerability, so-called vulnerability indicators, whose use can be justified in potentially contentious situations such as the allocation of priorities for support between nations. "From the perspective of the policy community, there is a real need to develop a set of metrics to measure and compare the relative vulnerability of one place to another" (Cutter 2003, p. 7). The second, equally important, policy imperative is that there is a need for improved understanding of the factors that shape vulnerability in order to develop measures aimed at increasing resilience and facilitating adaptation.

The primary objective of this paper is to identify key requirements that indicators of vulnerability to climate change must meet if they are to be of use in policy assessment. Specifically, at the meta-methodological level, we consider the standards by which approaches to the selection of vulnerability indicators and the construction of vulnerability databases must be judged. The need for a methodological framework to guide place-based (that is, sub-national) vulnerability assessments has been identified by Schröter et al. (2004), who developed criteria that such assessments must meet in order to effectively inform the adaptation decision-making process of local stakeholders. We base our assessment on an analysis of previous vulnerability indicator studies at the national level and explore the overarching challenges that vulnerability analysts face in generating credible databases. A lack of a clear theoretical and conceptual framework for the selection of indicators has hampered the robustness, transparency and policy relevance of previous studies. We seek to distinguish key elements of best practice that would enable these deficiencies to be effectively addressed. Our analysis suggests that the demand for credible vulnerability indicator studies can be best met through a process-based approach to indicator studies, that is, an approach based on understanding of the societal processes and mechanisms that determine levels of vulnerability. We argue that the processes that shape vulnerability have so far been inadequately captured by national-level indicator studies, which have often relied on aggregating static indicators of local conditions.

2. Data and Preliminary Analysis

In developing our assessment, we have analysed in detail five studies that develop national-level measures of vulnerability, as summarised in Table I. This selection represents published studies that measure societal (rather than simply sectoral or physical) vulnerability, using national data for at least 30 countries representing several continents.[1] In addition to this main dataset, we have examined relevant vulnerability studies on other spatial scales (mostly sub-national), as well as national-level indicator studies of other facets of society, such as sustainability and poverty, for lessons regarding best practice. By nature of their purpose, indicator studies tend to target an audience of policy-makers, decision-makers and practitioners and may well be published as institutional reports rather than peer-reviewed journal articles.

Previous national, continental- and global-scale climate studies with a quantitative basis aimed mainly to determine the potential extent and scale of climate change impacts in order to justify mitigation measures. See, for example, recent examples by Parry et al. (2004), and Voigt et al. (2004). These studies focused on the physical implications of the projected change in climate, often to the neglect of the human dimension (Kelly and Adger 2000). Yet to assist the development of policies that effectively address options for adaptation and hence reduce potential impacts, which is a rather different goal, there is a need, alongside any physical projection, to assess levels of vulnerability generated by social, economic, and political processes interacting across geographic scales. Such processes or driving forces of vulnerability may include urbanisation, environmental degradation, and ethnic tension and conflict (Cutter 2003).

Recent studies that include the human dimensions of climate vulnerability have tended to focus on the local to regional (sub-national) scale, often based on a case-study approach (see, for example, Jallow et al. 1996; Wilkie et al. 1999; Sousounis and Bisanz 2000). Some such studies have used vulnerability indicators at the sub-national level (for example, Ramachandran and Eastman 1997; Cutter et al. 2003; O'Brien et al. 2003, 2004). The reason for this concentration on lower spatial scales is that theoretical understanding of the processes that shape vulnerability is not well developed and the manner in which the multiple and often poorly defined processes that determine levels of vulnerability interact is clearest at the local level, the point at which they intersect. There are far fewer examples of attempts to assess vulnerability at a national level as a basis for global-scale comparison; the pioneering studies considered here represent an early stage in the development of a relatively new area of research.

The five studies that comprise our main dataset all address the issue of social vulnerability but vary in its definitions and the factors that are considered to determine vulnerability (Table I). Downing et al. (1995) identified three analytic variables in order to capture what they considered to be captured the main dimensions of vulnerability: food availability per capita; GNP *per capita*; and under 5 mortality. The selection was based on a conceptual definition of vulnerability based

TABLE I

A comparison of indicators used in five national-level indicator studies

Name and reference	No. of indicators	No. of countries	Indicators[a]			
			Environmental resources	Economic resources	Social conditions	Institutional capacity
Vulnerability-resilience indicators, Moss et al. (2001)	8	38	Settlement/infrastructure sensitivity, food security, ecosystem sensitivity, water resource sensitivity, environmental capacity	Economic capacity	Human health sensitivity, human and civic resources	
Environmental Sustainability Index, World Economic Forum (2002)	2 (reducing human vulnerability)	142	Basic human sustenance		Environmental health	
Dimensions of vulnerability, Downing et al. (1995)	3	172	Human ecology	Expanded entitlement	Political economy	
Index of Human Insecurity (IHI), Lonergan et al. (1999)	12	156	Water resources per capita, energy imports as percentage of consumption, food import dependency, access to safe water	GDP per capita	Urban population growth, fertility, maternal mortality, child mortality	Expenditures on defense versus health and education, degree of democratization, human freedom index
Country-level risk measures, Brooks and Adger (2003)	1	167	Population at risk (killed and affected) by climatic event			

[a]The categorisation of indicators was done as part of the analysis by the authors of this paper. While not shown here, proxy variables and measures used by each indicator were also considered to achieve a categorisation that reflected the focus of the different indicators in the most realistic way possible.

on considerations of human ecology, entitlement theory (Sen 1981) and political economics. Data for 172 nations for the year 1986 were compiled. Lonergan et al. (1999), in a study directed towards identifying vulnerable regions and providing a useful planning tool for decision makers, devised an Index of Human Insecurity (IHI) using vulnerability as a proxy for insecurity. Vulnerability, here, was defined in terms of exposure (physical risk) and capacity to respond. Variables included environmental (water, energy, food, sanitation), economic (GDP *per capita*), social (demographics) and institutional (priority attached to various forms of expenditure and degree of democratization and "freedom") data. National data were analysed from 1985 to 1995. The authors emphasise the importance of restricting the number of indicators to avoid overlap and intercorrelation and argue that qualitative data is "at least, if not more, important than quantitative information" in identifying regions of human insecurity. They also recommended the definition of a baseline or standard minimum set of indicators, which could be supplemented by other variables for use in sectoral analyses. Brooks and Adger (2003) made use of statistics related to natural disasters in assessing the risks associated with climatic variability. Several proxies for risk and vulnerability were developed. It was concluded that the number of people killed and otherwise affected by climate-related natural disasters over the final decades of the 20th century may be a reasonable proxy for climatic risk. Vulnerability was taken to represent the set of social, economic, political and physical factors that determine the amount of damage a given event will cause. It was argued that countries that are unable to cope with current climate hazards will be the most poorly equipped to cope with the adverse impacts of long-term climate change.

The Environmental Sustainability Index (World Economic Forum 2002) was devised to test the feasibility of creating an index that serves an analogous role to that of GDP regarding economic growth and aims to contribute to firmer foundations for environmental decision making. Human vulnerability to environmental impacts is one of five components of the index: a country is environmentally sustainable to the extent that people and social systems are not vulnerable. In this study, human vulnerability to environmental impacts is considered to be influenced by basic sustenance (measured by the proportion of undernourished in total population and access to safe drinking water supply) and environmental health (measured by child death rate from respiratory diseases, death rate from intestinal infectious diseases and infant mortality rate). Moss et al. (2001) developed quantitative indicators of sensitivity and coping that they termed vulnerability_resilience (VR) indicators. Here, vulnerability was defined as the propensity of a society, economic sector or ecosystem to experience damage or disruption as a result of a climate or other hazard. The authors sought to identify the socio-economic and environmental conditions that adversely affect the ability of different groups to adapt to climate variability and change, focusing on valued attributes of societies/economies, including food security, water availability, safety of settlements, human population health and ecosystem viability. They constructed a database for 37 countries covering the population at risk of flooding due to sea-level rise and statistics related to cereals

and animal production, land management, water resources, health, demographics, economic welfare and literacy. Following a sectoral assessment of vulnerability, the index for each sector was weighted in proportion to its importance for a particular population and then combined with information on macro-level factors that condition adaptation potential (such as GDP *per capita* and adult literacy rate) to determine the overall vulnerability of the population. Vulnerability estimates for climate and sea-level projections associated with four emissions scenarios produced by the Intergovernmental Panel on Climate Change (IPCC) were compared for selected countries.

A comparison of indicators and measures employed was carried out in order to distinguish the extent to which and how social factors are integrated into these five studies. Table I summarizes the ways in which these studies have attempted to define the environmental, economic, social and institutional bases of vulnerability. The table shows that the five studies exhibit a range of approaches and goals, varying in the extent to which they covered the four categories of environmental resources, economic resources, social conditions and institutional capacity. Only one study (Lonergan et al. 1999) included indicators that could easily be classified as covering all four categories, including institutional capacity. The indicators falling within these four categories also varied greatly, indicators related to social conditions, for example, ranging from human health sensitivity and human and civic resources (Moss et al. 2001) to political economy (Downing et al. 1995).

Table II compares the actual measures that have been used. There are substantial differences between the studies; however, some similarities emerge. Though commonality may simply reflect ease of data availability, three variables stand out in Table II: access to water/sanitation; GDP *per capita*; and infant mortality. The analysis also shows that, although social type indicators have been integrated in these studies (12 in total), there is still an overall emphasis on indicators related to environmental conditions and resource access (totaling 19 indicators in the five studies). Very few of the indicators used relate to economic and institutional conditions (totaling only four and three, respectively).

Significantly, the indicators are largely descriptive measures aggregating population characteristics. Vulnerability, like happiness, is a human state or condition that cannot be measured directly in any objective fashion. While it would be possible to define a subjective vulnerability index analogous to the measures used to estimate individual happiness (e.g. Lyubomirsky and Lepper 1999), based on a subject's responses to questions such as "How would you say you feel: very happy, pretty happy or not too happy?", existing studies have considered the factors that contribute to varying levels of vulnerability (economic health, for example) or else the consequences of heightened vulnerability (such as fatalities during natural disasters) rather than vulnerability itself. Furthermore, it is clear from previous studies that a critical distinction can be drawn between indicators that capture a characteristic of the population that is likely to contribute to vulnerability (for example, GDP *per capita*) and a measure of a process that might be thought to have an overarching

TABLE II

A comparison of measures used by five national-level indicator studies, grouped by type of indicator[a]

	Study					
Measures[b]	Vulnerability-resilience indicators	Environmental sustainability index	Dimensions of vulnerability	Index of Human Insecurity (IHI)	Country level risk measures	Total
Environmental resources						
Population at risk	×				×	2
Access to water/sanitation	×	×		×		3
Renewable water supply and inflow/ water resources per capita	×			×		2
Water use	×					1
Cereals production	×					1
Food import dependency ratio				×		1
Undernourishment		×				1
Animal protein consumption	×					1
Food availability per capita			×			1
Percentage land managed	×					1
Percentage land unmanaged	×					1
Fertiliser use	×					1
Population density	×					1
SO_2/area	×					1
Energy imports as percentage of consumption				×		1
Sub-total						19
Economic conditions						
GDP *per capita*	×		×	×		3
GINI index	×					1
Sub-total						4
Social conditions						
Fertility	×			×		2
Life expectancy	×					1
Dependency ratio	×					1
Literacy	×					1
Child death rate from respiratory diseases		×				1
Death rate from intenstinal infectious diseases		×				1
Under 5 mortality		×	×	×		3
Maternal mortality				×		1
Urban population growth rate				×		1
Sub-total						12

(*Continued on next page*)

TABLE II
(Continued)

Measures[b]	Study: Vulnerability-resilience indicators	Environmental sustainability index	Dimensions of vulnerability	Index of Human Insecurity (IHI)	Country level risk measures	Total
Institutional capacity						
Expenditures on defense versus health and education				×		1
Degree of democratisation				×		1
Human freedom index				×		1
Sub-total						3

[a]See Table I for details of the five studies.
[b]For the purpose of this analysis, the measures above are simplified where they reflect very similar focus or target (such as GDP *per capita* and market GDP *per capita*). The difference between these measures may nevertheless be significant in the actual process of quantifying vulnerability.

effect on the distribution of vulnerability (such as democratisation or globalisation). Clearly, in developing an interventionist strategy that will result in vulnerability reduction, a methodology that emphasises the causes of vulnerability is likely to be advantageous. We consider that, from this perspective alone, the policy relevance of existing studies, in that they largely focus on population characteristics rather than causal processes, is limited. Moreover, the lack of a process-based framework results in a static view of vulnerability, which, in reality, is a highly dynamic state (Eriksen 2000; Kelly and Adger 2000).

Three of the selected national-level indicator studies rank countries according to vulnerability, while the other two studies display findings as maps rather than in terms of an explicit ranking. The three studies that perform a ranking are not directly comparable since they differ in the number and selection of countries included in their dataset. Brooks and Adger (2003) include only ranking of the 20 most vulnerable countries while Moss et al. (2001) and World Economic Forum (2002) rank all countries. A comparison of their findings, presented in Table III, is still instructive. The comparison shows that there is a general agreement in terms of most of the countries ranked: the most vulnerable are developing countries and/or small island states. There are some notable exceptions such as Poland and Australia. There is, however, relatively little agreement regarding which particular countries are the most vulnerable, with only five countries ranked among the 20 most vulnerable in two or more of the studies and only one country ranked among the 20 most vulnerable in all three. This finding reflects the diversity of indicators and methodologies used. It firmly underlines the challenge in making objective judgments about which countries are more vulnerable than others as a basis for allocating of funding and the importance of ensuring that vulnerability indicator studies are as robust as possible.

TABLE III

Comparison of countries ranked among 20 most vulnerable[a] in three national-level indicator studies[b]

	Study		
Vulnerability rank	Vulnerability-resilience indicators	Environmental sustainability index	Country-level risk measures
1	Yemen	Angola	**Malawi**
2	India	Sierra Leone	Antigua & Barbuda
3	Tunisia	Ethiopia	Kiribati
4	**China**	Zaire	Guyana
5	Egypt	Somalia	Zimbabwe
6	**Bangladesh**	Chad	Philippines
7	Senegal	Liberia	**China**
8	South Africa	Guinea-Bissau	Australia
9	Libya	Niger	Swaziland
10	Thailand	Mozambique	Djibouti
11	Nigeria	Rwanda	**Bangladesh**
12	Ukraine	Burundi	Laos
13	Sudan	Zambia	Mongolia
14	Uzbekistan	**Malawi**	Kenya
15	Saudi Arabia	Haiti	**Iran**
16	Mexico	Madagascar	**Cambodia**
17	**Iran**	Guinea	Moldova
18	**Cambodia**	**Cambodia**	Tajikistan
19	Republic of Korea	Mali	Belize
20	Poland	Central African Rep.	Fiji

[a]Countries that feature among the 20 most vulnerable countries in two or more studies are marked in bold text.

[b]See Table I for details of the three studies.

This preliminary comparative analysis provided the basis for in-depth investigation of the sources of methodological diversity in these studies. In the following sections, we present the results of this analysis drawing, where relevant, on a range of other vulnerability studies generally undertaken at the sub-national level. Through meta-methodological analysis, that is analysis of over-arching methodological frameworks rather than technical details, we glean what the tables do not show, that is, the striking differences between the approaches taken in the five studies, differences that cannot be attributed to varying goals but to differences in theoretical understanding, assumptions and scientific method underlying the selection of indicators.

In the next section, we distinguish between two common approaches to the concept of vulnerability, identifying a process-based approach as most likely to result in policy-relevant conclusions. We then go on to consider how the policy usefulness of indicator studies can be enhanced, focusing on three aspects of the formulation of vulnerability indicators that have emerged from the studies considered in this assessment and that we consider particularly critical in the development of a credible set of measures.

The first area commonly cited as a critical concern in developing national-scale indicators (cf. Brooks and Adger 2003) is that of scale and aggregation. Scale and aggregation form one element of a wider set of concerns related to the selection of measures that are reliable, robust and representative. Second, we consider transparency in approach, discussing alternative methodological approaches and their implications. By transparency in approach, we refer to the practice of presenting a methodological account or conceptual framework that is clear and precise, free from ambiguity and easy to comprehend, and contains a full account of assumptions and potential strengths and weaknesses. Finally, we discuss a serious deficiency in existing studies, the limited testing and verification of indicators and of the validity of underlying conceptual frameworks. We consider how previous studies have approached these three issues and, identifying best practice, suggest ways in which policy usefulness can be enhanced in future indicator studies.

3. Assessing Vulnerability

In the previous section, we concluded that social conditions related to vulnerability have been integrated in past indicator studies to some extent, but the potential value of this research for adaptation policy assessment has yet to be realised. In this section, we argue that emerging understanding of vulnerability as a pre-existing state focuses attention on the processes creating these conditions. We examine how such a focus can enhance policy usefulness of indicator studies by guiding the selection of indicators that capture the processes shaping the state of vulnerability. Definitions of vulnerability vary (see, for example, Liverman 1990; Dow 1992; Downing et al. 1995; Cutter 1996; Kelly and Adger 2000; Turner et al. 2003) and the particular meaning of the term used in any analysis can be critical for the way that vulnerability may be studied or measured. One key distinction that has emerged is between vulnerability as the end point or as the starting point of an analysis (Kelly and Adger 2000). The 'end-point' approach uses the term vulnerability to denote the residual climate change impacts once adaptation has occurred. Previous studies of vulnerability at the global scale have mostly focused on particular sectors (such as water, agriculture or health) or aspects of exposure (such as flooding coastal areas) in order to develop sector-specific indicators of vulnerability (such as the number of affected people, water availability or food production *per capita*). (See, for example, Parry et al. 1999; Parry 2000; Arnell

2004; Nicholls 2004). For the most part, these studies have been undertaken with a view to defining the magnitude of the threat posed by the climate problem as a means of determining the need for political action to limit that threat and fall broadly into the 'end-point' category of analysing vulnerability. The 'starting-point' approach defines vulnerability as a pre-existing state generated by multiple factors and processes, such as political or economic marginalisation, that conditions the ability to respond to stress. The end-point/starting-point distinction roughly corresponds to the first and second-generation studies defined by Burton et al. (2002).

'End-point' studies, in defining vulnerability in terms of net impacts, inevitably frame adaptive options in terms of "fixes," often technological in nature, that will minimize particular impacts that have been projected. As a result, policy recommendations focus on identifying options for sectoral measures, such as introducing drought-resistant seeds or infrastructure changes specific to the projected change in climate parameters as these adjustments will, it is hoped, reduce net impacts and hence, following this definition, vulnerability. This restricts the nature and scope of the adaptive measures that are likely to be considered. Put simply, the question that tends to be asked is – What can be done to protect the population? In contrast, 'starting-point' analyses address fundamental causes and drivers of vulnerability and should, therefore, identify a broader scope of policy interventions. When vulnerability is taken as a starting point for analysis, technofixes represent only one of several sets of policy options. The question that often emerges from this type of analysis is – What can be done to strengthen people's own capacity to respond and adapt? That a 'starting-point' style of vulnerability analysis should lead to a broader range of adaptive options leads to a major conclusion of this discussion: that the demand for credible vulnerability indicator studies can best be met through a process-based approach to indicator studies, an approach based on understanding of what determines levels of vulnerability, rather than diagnostic population characteristics alone.

Using a 'starting-point' approach has three main implications for how vulnerability can be measured. First, the state of vulnerability is closely related to the ability to respond. Chambers (1989) has argued that vulnerability "has two sides: an external side of risks, shocks and stress to which an individual or household is subject; and an internal side which is defencelessness, meaning a lack of means to cope without damaging loss" (Chambers 1989, p. 1). Kelly and Adger (2000) define social vulnerability as the "capacity of individuals and social groups to respond to, that is, to cope with, recover from and adapt to, any external stress placed on their livelihoods and well-being" (p. 328). In this paper, we consider vulnerability, and the definition of vulnerability indicators, from this perspective of response capacity of human populations, taking due account of the fact that this vulnerability is shaped by both natural and societal factors.

An individual, a community or a nation is vulnerable if it is open to harm as a result of climate change or sea-level rise because its ability to respond to the threat

is limited. It follows that measurement of vulnerability must focus on the condition, shaped by existing circumstances, that determines the ability to respond to some future threat.

A second, and related, implication is that distinguishing between the processes of coping and adaptation is important when attempting to measure the ability to respond to adverse consequences. While often not explicitly addressed, and often assumed to be synonymous, the two are associated with different time scales and represent different processes, albeit sharing common elements (see, for example, Smithers and Smit 1997; Folke et al. 2002). We consider that the process of adaptation consists of adjustments in practices, processes or structures performed in response to the actuality or threat of *long-term* climate change and leading to an *evolving change in state* (defined in terms of both physical and social conditions). Coping refers to actions performed in response to the actuality of present climatic stress, often aimed at *restoring a previous state* and generally of a *short duration*. The two processes are, of course, related. For example, improving coping mechanisms represents an important component of an adaptive strategy. Recurrent short-term stress may also result in the evolution of coping strategies to the point where adaptation occurs.

The significance of this distinction between coping and adaptation for vulnerability indicator studies is that the factors that facilitate long-term adjustment (Yohe and Tol 2002) may be very different from the ones that enable response to a short-term hazard (Blaikie et al. 1994). Focusing on one type of factor rather than the other can determine the fundamental approach of any study and its conclusions. For example, focusing on the main elements of adaptive capacity in terms of technological, financial and institutional capacity (Yohe and Tol 2002) leads to the selection of indicators of economic resources, technology, information and skills, infrastructure, institutions, and equity (McCarthy et al. 2001). In contrast, indicators of coping capacity or entitlement may include poverty indices, inequality, proportion of income dependent on risky resources (Adger 1999; Adger and Kelly 1999) household demographics, food security, cereal market prices and access, livestock prices, income sources and diversification, household assets, and household dietary intake (Zambia National Vulnerability Assessment Committee 2003). Coping and adaptive capacity have often not been distinguished in past indicator studies. For example, Moss et al. (2001) employ one joint coping–adaptive capacity category of indicators, implicitly emphasising adaptive capacity. This may reflect a similar tendency by the IPCC (McCarthy et al. 2001). By not distinguishing between coping and adaptation, past studies have not captured important factors and processes shaping the way that people secure livelihoods and manage climate stress.

A third implication of considering vulnerability as a pre-existing state is that not only is vulnerability a condition that cannot be measured directly, as noted earlier, but that the consequences of this inherent inability to respond only materialize intermittently (for example, in a differential ability to secure well-being

during extreme climatic events). Vulnerability assessments at a sub-national level, such as those employed by Famine Early Warning Systems, have developed locally specific indicators of adversity as a close proxy for vulnerability, measuring emerging impacts, including effects on food stocks, livestock and food prices and vegetation (Lonergan et al. 1999; FEWSNET 2000; Ramachandran and Eastman 2000; Zambia National Vulnerability Assessment Committee 2003). In the context of anthropogenic climate change, a future threat, the approach of using proxy indicators for vulnerability based on *observed* impacts or adversity is not a viable option at this time. The emerging consequences of long-term climate trends on, for example, the occurrence of extreme weather events, while they may be related to global warming (Yohe and Tol 2002; Schär et al. 2004), cannot yet be distinguished clearly enough from natural variability (Mitchell and Karoly 2001). The only option is to use the impact of past climate hazards as a general guide to future vulnerability, in full awareness of the limitations of this approach (cf. Brooks and Adger 2003).

Below, we discuss how a process-based approach can be adopted in the selection of scientifically sound, policy-relevant indicators by focusing on three key problematic areas with regard to the methodologies supporting existing indicator studies. We consider the selection of indicators that are representative and policy relevant at the national level, transparent explanation of the conceptual and theoretical basis for assumptions made in indicator selection, and, finally, the verification.

3.1. Robustness: The selection of representative indicators

A focus on processes can guide the selection of representative indicators. Vulnerability is manifested at a point in space and time as a particular state. As noted earlier, though, the emerging policy focus brings with it pressure to go beyond local investigations of climate vulnerability to analysis at an aggregate level. The national level is often the favoured unit of analysis because it is believed that widely available and reliable indicators are to be found at this level that are comparable across nations. The nation state level is also still the main political unit through which emission targets and adaptation policies are formulated and resources, such as development assistance, are assigned (Fermann 1997; Cooper 2000; Klepper and Springer 2003). This is the sovereign level at which international negotiations take place, and at which level the ultimate responsibility for shaping the framework for policy formulation, instruments and institutional structures for executing measures lies, although Taylor and Flint (2000) also argue that the national level of analysis in political geography is promoted as a middle category to separate conflicting interests and that the global level is the level of reality where many influencing processes operate.

One of the main challenges in selecting representative vulnerability indicators at the national level, and in conceptualising vulnerability at that scale, derives from

the fact that the effects of climate-induced pressures are unevenly distributed in time and space, and they are mediated by society. Consequences vary between communities,[2] between social groups in a community, between households and between people within a household (Davies 1993; Guyer 1997; Adams et al. 1998; Morrow 1999). There are, for example, variations in the extent to which households are endowed with resources and the ability to convert these into food entitlements in times of stress. Watts (1983) found substantial differences in the way that households at different income levels cope with drought, the rich even being able to profit from stocking food and hiring labour at deflated prices. The ability of coping strategies to balance present consumption and well-being with future livelihoods (Corbett 1988) also depends on a number of informal sources of food and income such as social networks (Davies 1993; Swift 1993; Pottier 1988; Homewood 1995; Morrow 1999). The variation from one individual to another in knowledge, skills, and culturally and socially determined rights to resources (be it labour resources, monetary resources, agricultural production, or water or forest resources, cf. Sen 1981) according to gender and age are other determining factors (Nypan 1991; Denton 2002; Cannon 2002). The comparative advantage of households who possess particular skills or endowments of labour that obtain higher returns in some activities is an important factor in determining income diversification (Dercon and Krishnan 1996) and account for differences in their resilience to environmental pressures (Anderson and Woodrow 1991; Stigter 1995). Further, on a community level, social and organisational capacities, such as in decision making, and attitudinal and motivational capacities, such as shared belief systems, influence the capacity to respond to drought (Davies 1993).

Scale issues become of vital importance when attempting to select indicators at levels greater than the characteristic scale of vulnerability patterns in physical and/or societal space (Turner 1991; Polsky and Easterling 2001; Stephen and Downing 2001). When selecting robust vulnerability indicators, capturing patterns of local variability in some fashion in development of large-scale indicators is essential and should even extend to so-called pockets of vulnerability. The notion of pockets of vulnerability, that is, geographical areas or sectors of a community where factors and processes conspire to destroy response capacity, is closely related to criticality (Kasperson et al. 1996) and to "hotspots" in relation to threats to biodiversity (Myers et al. 2000). How can we ensure that such detail is not lost in the process of aggregation? At the national level, the use of indicators that seek to capture the processes that shape vulnerability, rather than to try to aggregate the state itself, provides, we argue, a suitable basis.

In targeting processes, it is particularly important to target the multiple and interacting pressures, environmental, social, economic and political, that face individuals, households, social groups and communities (de Waal 1989; Campbell 1999; Lonergan et al. 1999). This dynamism, as vulnerability evolves under the influence of a range of variable and varying factors, leads to great variation in levels of vulnerability over space and time. Another aspect of the dynamic of vulnerability is

that coping and adaptation are characterized by a continual changing of strategies to take advantage of available opportunities (Campbell 1999; Eriksen 2005). Capturing a snapshot of vulnerability at a particular moment of time is to miss the richness of the process. It is a challenge for vulnerability indicator studies, then, to capture the dynamic aspects of vulnerability and the processes that cause this dynamism. Leichenko and O'Brien (2002) suggest using dynamic indicators signifying patterns of change, such as change in access or levels of investment, change in terms of trade, change in HIV/AIDS rates and escalation of conflict. These are more useful than static indicators signifying state, such as share of drought resistant crops, infant mortality or female literacy, in capturing the processes of economic liberalisation and globalisation, respectively, and their impact on vulnerability. From a policy perspective, understanding the processes that determine how levels of vulnerability change over time is arguably more important than understanding why a particular pattern of vulnerability exists at a point in time, as it is change we are trying to engender through intervention (Kelly and Adger 2000).

Processes and their interaction have so far not been well captured in national-level vulnerability indicator studies. Lonergan et al. (1999) suggest that studies aimed at identifying vulnerable regions should include both driving force indicators, which reflect key structural relationships, and state indicators, which reflect functional relationships and process flows within the system. Downing et al. (1995) propose that political economy, arguably a structural facet of society, be included as one of three dimensions of vulnerability. Other studies (Lonergan et al. 1999; Moss et al. 2001) include indicators such as income distribution and GINI[3] index which may indicate the manifestations of such processes; however, specific political or economic structures or processes have so far seldom been explicitly targeted. Table I shows that among the five studies selected for comparison, aggregate conditions such as settlement/infrastructure sensitivity, environmental health, and water resources per capita are measured rather than processes creating these conditions. The low number of economic or institutional-related indicators used in total in the five studies (four and three, respectively) may reflect the difficulties involved in identifying indicators of economic or political processes. So far, no national-level study has attempted to comprehensively capture processes that shape vulnerability. The relevance of existing indicators to processes, and thus the success with which processes are captured, can only be identified if the particular processes are clearly distinguished in each study. In order to be representative at the national level, indicators must capture processes that operate at this level. By attempting to aggregate local level, static data, studies miss both the true significance of vulnerability by potentially masking pockets and hotspots of vulnerability and failing to identify where critical driving forces of vulnerability operate. These are two facets of vulnerability that policies to reduce vulnerability must target, hence a failure to capture them reduces the policy usefulness of national-level indicator studies.

The identification of processes that could be targeted may be assisted by lessons drawn from past local-level studies as well as qualitative studies. To give one

example of understanding that might underpin a process-based approach, the concept of entitlement has been central in describing how people's command over resources is related to the ability to secure food or income and strategies to prepare for and recover from climatic events and change (Gore 1993; Guyer 1997; Adger 2000). In particular, it is emphasised that while environmental factors may lead to a drop in food production, other social factors, such as market failure, determine whether or not a household can achieve food security and draw on alternative sources of food and income (Sen 1981; Drèze and Sen 1989). Food production decline can be an important cause of entitlement failure for small-scale food producers, who derive their entitlements from producing food; however, exchange entitlements decline, when prices of food soar and prices of assets plummet, is also important as demonstrated by, for example, Devereux and Næraa (1996) in their study of the 1992/1993 drought in Zambia. Experiences from Latin America suggest that several processes affect the way that local livelihoods are secured and, implicitly, any pattern of coping and vulnerability. These processes include the capitalisation of farms, rural proletarisation, migration, and the emergence of rural industry and rural and periurban commerce (Bebbington 1999).

In national-level indicator studies, it may be important to capture the factors and processes that operate on scales higher than the household or community level and that in part determine the existence of opportunities when faced with a climatic event and the way in which command over resources is secured. Jodha (1995), for example, argues that fragile zones are characterised by environmental, economic and political threats that limit their opportunities. Famines or human adversity occurs in a broad political, economic and ecological context. Multiple natural and man-made phenomena, rather than one single cause, combine to produce famine (Vestal 1991). The underlying causes of individual entitlement or livelihood failure are the political and economic structures of resource ownership and control. Examining the structural causes of vulnerability to flood hazard in Pakistan, Mustafa (1998) concludes that the main cause of the vulnerability of the studied communities was disempowerment processes.

In distinguishing processes that shape vulnerability, local-level studies can form a useful starting point (Wilbanks and Kates 1999). The processes, structures, stresses and phenomena that shape vulnerability do, however, operate on range of different geographic and societal scales and may have different effects at different levels, feeding back to the local nexus where vulnerability is manifest. It is necessary to capture this interplay between large-scale processes and local patterns of vulnerability in any set of indicators (Brooks and Adger 2003). For example, decreasing labour availability exemplifies a constraint on coping at household or community level; a national-level indicator may aim to capture the processes that shape this local decrease in labour availability such as urbanization and de-agrarianisation. Other processes that can be targeted include those contributing to any erosion of traditional systems of social security in Third World societies, such as increased market penetration (reorientation of most production away from local circulation

and reciprocity), population growth (fewer unappropriated flexible resources) and rise of the modern state system (provides services) (Platteau 1991). Further, it has been argued that the privatisation of land and degradation of common lands (Jodha 1990), loss of diversity in livelihoods (Netting 1993, Ellis 1988) and the declining health status of the population (UN Office for the Coordination of Humanitarian Affairs 2003) lead to increasing vulnerability. Of course, there are obvious limitations to the national scale as a unit of analysis, since there are important processes shaping vulnerability that operate on sub-national as well as supra-national scales. The survey of processes must extend beyond the nation state (Leichenko and O'Brien 2002). State sovereignty is increasingly limited, for example, by the activities of transnational corporations involved in production, trade and finance (Fermann 1997). In addition to globalisation, the process of localisation affects the traditional role of the nation as a provider of security to individuals and it is individuals and communities rather than nation states who face the greatest risks (Lonergan et al. 1999). Nevertheless, a focus on processes is likely to capture most representatively vulnerability at the national scale.

3.2. Transparency in approach: Defining the conceptual framework

Conceptual frameworks have a particularly important role to play in developing process-based approaches to measuring vulnerability. Cutter (2003) argues that the development of vulnerability indicators has been hindered by a lack of conceptual development regarding, for example, the most appropriate metrics and scale. Taking scale as a starting point, it is inevitable that simplifying assumptions will be necessary in developing aggregate indices at, for example, the national level (World Economic Forum 2002; Jollands and Patterson 2003). Though the breaking down of complex systems and causations of environmental change into components has sometimes been criticized as reductionist (Gustafsson 1998), simplification, if successful, enables the investigation of the most important interactions (World Economic Forum 2002). Indicators of sustainability, for example, attempt to capture complex and diverse processes in relatively few measures (Bell and Morse 1999). There may not be agreement on which assumptions to use, however, nor may they be obvious or made explicit. The complexity of processes shaping vulnerability may render it tempting to give up conceptualising the understanding of vulnerability that we argue must underlie the selection of indicators. Blalock (1984) observes, however, that when links between phenomena are well understood, measurement can be direct, but that in social sciences, social mechanisms are multivariate and indeterminate. Precisely because of the complexity, it is all the more important to outline a conceptual framework so that assumptions about how processes shape vulnerability underlying indicator selection can be assessed.

The development of a conceptual framework is particularly important in national-level indicator studies in order to facilitate the use of aggregate data

(Retzlaff 1968). In addition, the conceptual tools that are developed need to recognize the multivariate character of the processes under analysis. The computation of an index relies on conceptualization of the relationships between indices (Niemeijer 2002). There are numerous methodological assumptions that are made in the aggregation of indices, not least in the weighting of different variables (World Economic Forum 2002; Niemeijer 2002). The theory inter-relating postulated causes has to be well specified and assumptions well understood in order for an indicator study to be verifiable and comparable, and in order to allow the improvement and updating of such exercises when new knowledge about vulnerability becomes available. Assessing the Human Development Index (HDI), Sagar and Najam (1998), test its applicability by examining the validity of the conceptual basis for the construction of the index. The examination enables them to argue that the HDI presents a distorted picture of the world due to faulty assumptions and factors ignored, in terms of the application of additivity of key development dimensions as well as the under-representation of income disparities. They also suggest how the index can be improved. The study underscores the recommendation by Moss et al. (2001) that the methodology used to construct vulnerability indicators be transparent and understandable. In a case such as this, where the consensual knowledge base is limited, taking care in perceiving and defining the problem becomes all the more important and should be an iterative, participatory and ongoing process (Bell and Morse 1999).

The sources of diversity in study approaches evident in Table II can be summarized in terms of a crude typography, inclusive/comprehensive as opposed to selective/limited in terms of the number of variables employed. This typography does, however, mask a more philosophical distinction between those studies basing the selection of indicators on some theoretical understanding of the factors determining levels of vulnerability and those adopting a more empirical, evidence-driven approach. Thus, two different approaches have been used in selecting vulnerability indicators: one based on a theoretical understanding of relationships and the other based on statistical relationships. In his review of national environmental indicators, Niemeijer (2002) makes a broad distinction between the parallel theory-driven approach, where the best possible indicators are selected from a theoretical point of view, and a data-driven approach. The first represents a deductive research approach and the second an inductive research approach. Conceptual understanding plays a role in both and is central to maintaining transparency of assumptions.[4]

The deductive approach to selecting indicators involves identifying a set of relationships on the basis of theory or some conceptual framework and selecting indicators on the basis of these relationships. Identifying the best possible indicators involves the "operationalisation" of concepts. In deductive research, a hypothesis is tested by operationalising the concepts within it, collecting appropriate data and then examining the proposed relationships between the concepts. In this sense, operationalising specifies the way in which theoretical concepts will be measured, or the indicators used to measure the concept (Blalock 1984). The first step in a

deductive or theory-based approach lies in understanding the phenomenon that is being studied and the main processes that are involved. The second, reductionist, step involves identifying the main processes to be retained for study and how they are related. The third step in a theory-driven indicator study involves selecting the best possible indicators for these processes and assigning values and weights (Niemeijer 2002). Because bounding the risks and factors selected for study of real-world vulnerability involves subjective decisions (Briguglio 1995; Cutter 2003), it is particularly important that a deductive procedure is transparent. The significance of the results of this kind of study can be assessed on the basis of the validity of theoretical approach and assumptions, the appropriateness of the selected indicators and the reliability of data.

A strong theory-driven conceptual framework forms the basis for identifying vulnerability indicators if a deductive approach is taken. Downing et al. (1995), for example, conceptualise vulnerability as depending on the human ecology of production, expanded entitlements of market exchange, and political economy. This drives their selection of indicators measured, namely, food availability in kilocalories per day per capita, GNP per capita, and under 5 mortality per 1000. In a study of vulnerability in the Red River delta of Vietnam, Adger and Kelly (2000) identify income levels, income inequality and diversity of livelihood as key indicators on the basis of their conceptual framework, the architecture of entitlements. While the earlier two studies are notable exceptions, the particular approach is seldom made explicit in indicator studies. A more common approach is that adopted by Moss et al. (2001) who, rather than providing an explicit theoretical framework, select factors that have been identified in past studies as influencing vulnerability and organize them around two main elements: sensitivity, and coping and adaptive capacity.

The inductive approach to selecting indicators involves relating a large number of variables to some measure of vulnerability or its consequences in order to identify the factors that are related to a statistically significant extent. The inductive approach involves a "hoovering" of potentially relevant indicators then a winnowing based a test of statistical significance to identify appropriate indicators. For example, Ramachandran and Eastman (1997) apply 92 variables used with 539 potential values for each variable (7 years across 77 administrative sub-divisions) to account for the average number of people in need of food assistance in West Africa. Indicators include Normalised Difference Vegetation Index, prices of livestock and food grains, agricultural production, demographic data and large-scale agricultural survey results. Through statistical methods, the different contributions of the different variables to vulnerability were assessed. Other studies have investigated statistical relationships using a smaller selection of variables. Kamanou and Morduch (2002), studying vulnerability to poverty in Côte d'Ivoire, build regression models between selected indicators of vulnerability (*per capita* expenditures, household size, age of head, literacy and numeracy of head, and nationality) and consumption. Yohe and Tol (2002) investigate the statistical relationship between

hypothesised determinants of adaptive capacity to climate change at the national level (*per capita* income, education, life expectancy, land area, political rights and civil liberties, and income inequality) and a measure of numbers of people killed by natural disasters, the number of people injured, made homeless or otherwise affected, and material damage by natural disasters.

The next step in an inductive approach would be assessing the extent to which the findings can be generalised, and explaining the relationships that make the identified variables important determinants of vulnerability. Inductive research makes use of empirical generalisations, finding of patterns in data, filled with empirical content and statements of empirical regularities. These generalisations can be used to build conceptual models and to develop theory. Identifying good theoretical explanations for the factors found to statistically explain vulnerability is also one way of verifying that appropriate indicators have been found and that results are meaningful. Ramachandran and Eastman (1997) suggest that their results indicate that a direct human suffering element, poverty, and an indirect element, economic loss in the event of drought, drive the geographic distribution of vulnerability. Yohe and Tol (2002) also offer explanations for their findings, namely that only *per capita* income and income inequality are significantly related to adverse effects by natural disasters. Few indicator type vulnerability studies explicitly discuss implications of their findings for vulnerability theory, however. Kamanou and Murdoch's (2002) study of economic vulnerability provides some valuable lessons for climate vulnerability studies in this regard. They set out a conceptual framework based on six alternative theoretical starting points to capturing vulnerability, including expected utility theory, mobility measurement, vulnerability as variability, risk of change in poverty status, ability to cope, and asset status. Through this analysis, they are able to yield the finding that their method, rather than the specific resulting regressions, can be applied in other contexts. They also add to current understanding by concluding that economic vulnerability is best interpreted in terms of future possible outcomes for households rather than current poverty.

Elements of a conceptual framework may be considered at the outset in inductive research in order to frame the collection of data. The use of a conceptual framework and operationalization is, however, frequently less rigorous in inductive research than in deductive methods and the testing of hypotheses is often less formal. In fact, it is characteristic of many vulnerability indicator studies that their conceptualisation and hypothesis testing approaches are not easily distinguishable as either deductive or inductive in method because they often lack both a clear theoretical justification and empirical or statistical method for indicator selection.

Typically, indicator studies, particularly at the national level, base their selection of a multitude of indicators on a rather rudimentary theoretical appreciation of vulnerability (which is often, it is only fair to say, all that is available). Vulnerability may be seen as a result of high exposure to a hazard and a low coping ability (Ramachandran and Eastman 1997) or of sectoral sensitivities, and coping and adaptive capacity (Moss et al. 2001). The analysts then identify categories of indicators,

such as settlement/infrastructure sensitivity, food security, economic capacity, human and environmental resources, economic capacity and human development or sustenance (Moss et al. 2001; World Economic Forum 2002), on the basis of this framework. Moss et al. (2001) represent a promising example of transparent approaches to indicator study, thoroughly presenting the assumptions made regarding what the individual proxies represent. No explicit theoretical justification is made, however, for why the particular five sectors of climate sensitivities and three sectors for coping and adaptive capacity are more appropriate than alternative sectors not selected. In fact, few studies thoroughly discuss how categories of indicators or proxies are linked theoretically and conceptually to any basic understanding of vulnerability or explicitly utilize theory to inform further indicator selection within each category, as recommended by Lonergan et al. (1999). A similar tendency that relations between indicators are not made explicit has been observed among environmental indicator studies (Niemeijer 2002).

Studies that closely integrate theory, conceptualization and indicator selection are more commonly performed at the sub-national level, such as in a case study of Georgetown County, South Carolina (Cutter et al. 2000), a study of coastal counties in the United States (Heinz Center 2002) and a study of three global coastal cities (Schiller et al. 2001). Schiller et al. (2001), for example, conceptualise the relationship between stresses and an exposed system, suggesting that endowments, direct coping abilities and indirect coping (social safety net/support, social contact) are important components of system characteristics and selecting indicators for each of these components. Similarly, the selection of indicators in a study on sub-national level in Vietnam is based on a theoretical framework conceptualizing, operationalising and measuring individual and collective vulnerability as the main elements of social vulnerability (Adger 1999).

While employing a looser conceptual framework is consistent with inductive research methods, national-level indicator studies seldom relate the distribution of vulnerability in time or space statistically to an end-result adversity or other independent measure of vulnerability. This is not least because finding a meaningful measure of end-result adversity or vulnerability at the national level against which vulnerability indices can be run to form statistical relationships represents a major challenge. Databases regarding mortality and the numbers of people adversely affected by climate-related events have poor data coverage for certain time periods and countries (Brooks and Adger 2003). There are also problems of data reliability; for example, life loss may be underreported in developing countries (Yohe and Tol 2002). Other data more appropriately representing the severity of impacts of climate-related disasters, such as data regarding economic damage, are sparse and difficult to estimate or interpret. For example, data on insurance claims may over-emphasise impacts on wealthy nations as these have the greatest material losses in terms of insured economic values; the actual material losses and threats to livelihoods experienced by uninsured poorer households in developing countries are not well captured (Münchener Rückversicherungs-Gesellschaft 2002;

Voss and Hidajat 2002; Yohe and Tol 2002; Brooks and Adger 2003). Brooks and Adger (2003) develop proxies for the consequences of climatic events at the national level, combining data concerning mortality and total numbers affected by hazards with population data. As they note, though, there are important aspects of vulnerability, such as the uneven distribution of risk within countries as well as the vulnerability of socially marginalized groups that are not captured by such proxies.

3.3. The processes that shape vulnerability: Verification

Verification of indicators is an important end in its own right, conveying authority and credibility to the set of measures, but it also contributes to improving understanding of vulnerability and hence the representation of processes in indicator studies. In the case of the deductive approach, verification involves assessment of the goodness of fit between theoretical predictions and empirical evidence. To some extent, this work will have been undertaken before the indicator study was started, as existing theory provides the basis of the deductive approach. But the indictor study then provides a framework for further testing and verification and the further development of the conceptual framework. In the case of the inductive approach, the statistical analysis, if conducted rigorously, must incorporate verification of any results through testing on independent data as an aspect of good practice. Having said that, for a variety of reasons, verification has been limited in existing studies of climate vulnerability indicators.

The selection of indicators and the measurement process represent a theoretical reasoning and prediction (Blalock 1984). The indicators selected on the basis of the deductive approaches can be tested against measures of adversity evident in the observed outcomes of past climatic events, as analogues of possible future conditions (Parry and Carter 1998). The adversity encountered in connection with a particular event can be measured more or less directly using well-established measures such as death, illness, hunger or loss of property (FIVIMS 2000, Brooks and Adger 2003), although, as discussed earlier, available national-level data are not unproblematic. Such a test is highly context specific, given that the dynamic nature of vulnerability cannot be fully captured by a snapshot in time at a particular point in space. Moss et al. (2001) propose that past case studies collectively "provide a benchmark with which to corroborate qualitative assessments of adaptive capacity" (p. 5). Parry and Carter also suggest that analysis tools can be tested and evaluated through conducting 'microcosm' case studies, small-scale pilot studies under conditions representative of the main study. An example of an indicator study that performs such verification is the Heinz Center study (2002) of the United States, albeit at county rather than national level. The study provides a conceptual framework of vulnerability and a description of the understanding of vulnerability that underlies the selection of factors for investigation. The list of selected population characteristics influencing social vulnerability is found to explain 80% of variation

in vulnerability among US coastal counties and the results are verified through two in-depth case studies.

In the case of the inductive approach, verification through the use of independent data, perhaps through sub-sample replication, data is one of the means of testing the reproducibility of the identification of patterns in the data. Study findings can also be evaluated through comparison with the outcome of other relevant studies. With relatively few climate vulnerability indicator studies carried out at the national level, it may be necessary to compare results with indicator studies focusing on related issues, such as poverty (Sahn and Stifel 2000), human development (World Bank 1997; UNDP 2003) or environmental sustainability (World Economic Forum 2002), as well as studies focusing on the sub-national scale (Adger 1999) and qualitative and expert judgment data (Parry and Carter 1998; Parry 2000).

One of the fundamental difficulties in devising verification exercises is that all must, inevitably, be based on present-day data and this means that indicators are being tested in the context of coping rather than adaptation, limiting the extent to which findings can be generalised. As noted earlier, the processes of coping and adaptation differ from one another and policies that favour one may not necessarily facilitate the other. Another problem that indicator studies face is that of finding reliable data (Parry and Carter 1998), whether it be data representative of the processes that determine vulnerability or measures of adversity such as deteriorating food security or increasing under-nutrition and other health problems (Haddad et al. 1994; Parry et al. 1999; McCarthy et al. 2001). One consequence of the limited availability of data is that the selection of indicators is severely constrained, and the agreement between studies in terms of chosen measures is often more a function of availability than a convergence of insights. This state of affairs also, in part, explains, though cannot justify, the lack of thorough verification evident in previous work. The need for verification is, however, particularly great given the complexity of the issues, the lack of complete understanding and the many assumptions made in vulnerability analysis.

4. Conclusions

The fundamental lesson that emerges from this assessment is the need to enhance our understanding of the causes of vulnerability in order to develop vulnerability indicators that can effectively aid policy development. Existing national-level indicator studies display a number of weaknesses that limit their usefulness in developing adaptation policy. Our analysis shows that these studies have emphasised the measurement of aggregate conditions that provide static snapshots of population characteristics rather than guidance on societal processes that can be targeted to reduce vulnerability.

We have identified three areas that warrant serious attention in future studies. First, given the differentiation of vulnerability at all levels, scale issues are a critical concern in selecting representative indicators. The fundamental scale of

vulnerability, primarily because of differentiation within the community, is local, though processes operating at broader spatial scales do contribute significantly to patterns of vulnerability at this level. The need to aggregate up to, say, the national scale can lead to the loss of information about pockets of vulnerability and may distort overall conclusions as detail is lost in the process of averaging or accumulation. The dynamic nature of vulnerability, deriving from the interaction of the many processes that determine vulnerability and the constant evolution of levels of vulnerability as adaptation takes place, must also condition the selection of indicators. Not only does it suggest that a wide-ranging set of indicators is needed but also that these indicators must be updated regularly as reliance on a single snapshot in time could be seriously misleading. Any process-based study must, of course, consider change over time as a key diagnostic tool. The dynamic of vulnerability suggests that any attempt to 'understand' the causes of vulnerability must be undertaken with due awareness that understanding too must evolve as vulnerability itself changes.

Second, the authors of indicator studies should be more transparent in defining assumptions and premises. Diverse definitions and uses of concepts, as well as a conflation of purposes and assumptions, have been observed. While diversity in approach is more than appropriate at the development stage of a field of study, the increasing demand for objective analysis of vulnerability to support resource allocation and, ultimately, adaptive strategies warrants a clearer definition of where any study fits into the morphology of vulnerability assessment. Explicit statement of underlying assumptions and premises and potential effects on research outcome is fundamental to the scientific method and is vital if the results are to be compared across different studies, leading to the development of a more thorough conceptual understanding.

Third, in addition to transparency, verification of findings is an aspect of vulnerability indicator studies to which insufficient attention has been paid. It is important to note that reliable, verifiable conclusions can only be drawn from one component of the complex of response patterns, that is, the observed success in coping with short-term climate variability in terms of populations avoiding adverse consequences when faced with climatic events. Extrapolation to the longer-term process of adaptation can only be undertaken with caution and continual monitoring of any intervention strategy. Nevertheless, verification is absolutely essential if indicator studies are to generate findings that are credible both within the scientific community and before those responsible for the development and implementation of adaptation policies. The findings of this study underscore the urgency for global change research of enhancing the understanding of the multiple pressures that shape vulnerability.

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Notes

1. To our knowledge, this selection represents all such studies currently published in journals, books, or publicly available research reports.
2. A community, in this context, refers to looser forms of social organisation in which either space or common interests are the defining characteristics (Blaikie 2000).
3. The GINI coefficient is an index of concentration, or a measure of the equality of distribution.
4. The deductive and inductive approaches in identifying vulnerability indicators have a parallel in the two types of climate modelling, that is dynamic modeling, based on our understanding of physical relationships, and statistical modeling, based on observed empirical relationships.

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