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The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation

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Abstract

We present a set of indicators of vulnerability and capacity to adapt to climate variability, and by extension climate change, derived using a novel empirical analysis of data aggregated at the national level on a decadal timescale. The analysis is based on a conceptual framework in which risk is viewed in terms of outcome, and is a function of physically defined climate hazards and socially constructed vulnerability. Climate outcomes are represented by mortality from climate-related disasters, using the emergency events database data set, statistical relationships between mortality and a shortlist of potential proxies for vulnerability are used to identify key vulnerability indicators. We find that 11 key indicators exhibit a strong relationship with decadally aggregated mortality associated with climate-related disasters. Validation of indicators, relationships between vulnerability and adaptive capacity, and the sensitivity of subsequent vulnerability assessments to different sets of weightings are explored using expert judgement data, collected through a focus group exercise. The data are used to provide a robust assessment of vulnerability to climate-related mortality at the national level, and represent an entry point to more detailed explorations of vulnerability and adaptive capacity. They indicate that the most vulnerable nations are those situated in sub-Saharan Africa and those that have recently experienced conflict. Adaptive capacity—one element of vulnerability—is associated predominantly with governance, civil and political rights, and literacy.

Keywords: Vulnerability; Adaptive capacity; Indicators; National-level; Risk; Mortality; Delphi survey; Governance; Literacy; Health

1. Introduction

The purpose of this study is to develop national-level indicators of vulnerability and capacity to adapt to climate hazards. The national level is an appropriate scale for information utilised by central government in determination of policy. In other policy areas, the UNDP's Human Development Index, measures of Genuine Progress and other indicators provide comparable, transparent and meaningful information on aspects of development, though often fail to capture environmental sustainability (Neumayer, 2001; Lawn, 2003; Bell and Morse, 1999). Comparing vulnerability across countries can identify leverage points in reducing vulnerability to climate variability and, by inference, to climate change, which is likely to be manifest through changes in the frequency and severity of existing hazards at least in the short- to medium-term (Easterling et al., 2000; Frich et al., 2002). Identification of particularly vulnerable nations or regions (i.e. those that are least well equipped to cope with the impacts of climate change) can act as an entry point for both understanding and addressing the processes that cause and exacerbate vulnerability (Moss et al., 1999; Yohe and Tol, 2002; Brooks and Adger, 2003; Leichenko and O'Brien, 2002; O'Brien et al., 2004), although sub-national spatial and social differentiation of

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vulnerability, and the way in which the impacts of national-scale processes are mediated by local conditions, should not be downplayed.

Published studies of national-level vulnerability to date generally have been characterised by indicators chosen subjectively by the authors, based on assumptions about the factors and processes leading to vulnerability, informed by literature review and intuitive understandings of human–environment interaction. The approach presented here uses an empirical approach to develop indicators of vulnerability to a range of climate hazards at the national level. We specifically address vulnerability to mortality resulting from exposure to climate hazards, assessed at the national level for decadal periods. This analysis is carried out using a conceptual framework in which risk is viewed as a function of physically defined climate hazard and socially constructed vulnerability, elaborated in the following section.

National-level outcome risk is represented in terms of mortality outcomes from climate-related disasters using data from the emergency events database (EM-DAT) data set. Vulnerability is represented by a suite of socio-economic, political and environmental variables that represent the sensitivity and exposure of national populations to climate hazards. Key indicators of vulnerability are identified by examining the statistical relationships between a large number of potential proxies for vulnerability, and measures of mortality outcome.

The paper also addresses validation of the indicators through expert elicitation, and an assessment of the sensitivity of country rankings to different sets of weightings, based on subjective weightings generated by a focus group. Finally, a set of "most vulnerable" countries is identified via an assessment of country rankings across a number of composite indicators, each constructed using a different set of weightings, and the implications of the study for adaptation discussed.

2. Conceptual framework: risk, vulnerability and adaptive capacity

2.1. Defining the relationship between vulnerability and risk

Definitions of risk are commonly 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 (Smith, 1996; Stenchion, 1997; Downing et al., 2001; Brooks, 2003; Jones and Boer, 2003). In this study, risk is conceptualised as relating to compound "climate-related disasters", triggered by climatic or meteorological hazards (storms, droughts, extreme precipitation events, circulation changes and so on) but mediated by the sensitivity or vulnerability of the exposed systems. We therefore view risk as a function of hazard and vulnerability (UNDHA, 1992), a definition which is compatible with that of risk as the product of probability and consequence (Smith, 1996; Brooks, 2003; Jones and Boer, 2003). In this study, conducted at a global scale and focusing on the national level, the exposed systems are individual countries, and we are concerned with mortality risk.

As an alternative to the probabilistic approach, we may use quantitative measures of outcome as proxies for risk, particularly where we are concerned with historical data. Probabilistic and outcome-based measures represent alternative but complementary ways of approaching risk assessment. In particular, we may use data relating to adverse socio-economic impacts as a retrospective measure of historical risk, representing outcomes arising from the interaction of hazard and vulnerability (UNDHA, 1992; Brooks, 2003). Here we use numbers of people killed by climate-related disasters per decade, expressed as a percentage of national population, as a proxy for climate mortality risk at the national level. We then use the relationship "risk = hazard × vulnerability" to assess vulnerability using the risk proxies in conjunction with a variety of socio-economic and other data.

2.2. Factors influencing vulnerability

The IPCC Third Assessment Report (TAR) contains two conflicting definitions of vulnerability. The glossary of the TAR (IPCC, 2001, p. 995) defines 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." However, Smit et al. (2001) in the IPCC TAR, citing Smit et al. (1999), describe vulnerability as the "degree to which a system is susceptible to injury, damage, or harm (one part—the problematic or detrimental part—of sensitivity)". Sensitivity in turn is described as the "degree to which a system is affected by or responsive to climate stimuli" (IPCC, 2001, p. 894). Here we use the latter definition, in which vulnerability is essentially a state variable, determined by the internal properties of a system; for social systems, we are considering what may be referred to as *social vulnerability* (Brooks, 2003; Adger, 1999; Adger and Kelly, 1999; Kelly and Adger, 2000).

Vulnerability depends critically on context, and the factors that make a system vulnerable to a hazard will depend on the nature of the system and the type of hazard in question. The factors that make a rural community in semi-arid Africa vulnerable to drought will not be identical to those that make areas of a wealthy industrialised nation such as Norway vulnerable to flooding, wind storms and other extreme weather events. Isolation and income diversity might be important determinants of vulnerability to drought for rural communities in Africa, whereas the dominant factors mediating vulnerability to storms and floods in Norway might be the quality of physical infrastructure and the efficacy of land use planning. Nonetheless, there are certain factors that are likely to influence vulnerability to a wide variety of hazards in different geographical and socio-political contexts. These are developmental factors including poverty, health status, economic inequality and elements of governance, to name but a few. These may be referred to as generic determinants of vulnerability, as opposed to specific determinants relevant to a particular context and hazard type, such as the price of a particular food crop, the number of storm shelters available for the use of a coastal community, or the existence of regulations concerning the robustness of buildings. Although the relative importance of different generic factors will exhibit some variation, such factors may be viewed as the foundation on which specific measures for reducing vulnerability and facilitation adaptation are built. For example, a rural community is more likely to be serviced by transport infrastructure if it is effectively represented at the political level. Building codes are more likely to be enforced if corruption in the building industry and regulatory agencies is minimised.

The concept of generic, as opposed to hazard- and context-specific, determinants of vulnerability, is a useful one if we wish to undertake comparative assessments of vulnerability at the national level. While developmental and governance indicators do not represent a complete description of vulnerability, and while vulnerability will exhibit substantial sub-national geographical and social differentiation, assessments of "generic" vulnerability can tell us how well equipped a country is to cope with and adapt to climate hazards. The aim of the study presented here is to identify key indicators of generic vulnerability from general developmental data representing the national level, using the risk–hazard–vulnerability framework outlined above, in a global analysis.

2.3. Relationships between vulnerability and adaptive capacity

Adaptive capacity is defined in the glossary of the IPCC (2001, p. 982) TAR as "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." Because adaptation does not occur instantaneously, the relationship between adaptive capacity and vulnerability depends crucially on the timescales and hazards with which we are concerned. The vulnerability, or potential vulnerability, of a system to climate change that is associated with anticipated hazards in the medium- to long-term will depend on that system's ability to adapt appropriately in anticipation of those hazards. However, vulnerability to hazards associated with climate variability that may occur in the immediate future will be related to a system's existing short-term coping capacity rather than its ability to pursue long-term adaptation strategies. For a more detailed discussion of the relationship between vulnerability and adaptive capacity within the context of different types of climate-related hazard the reader is referred to Brooks (2003).

3. Data and methods

3.1. Proxies for risk

The study presented here specifically addresses mortality risk associated with climate-related disasters and, by extension, deals with vulnerability to death associated with climate hazards. It is therefore not a comprehensive assessment of all the dimensions of vulnerability, focusing instead on the most important dimension, and the one for which relatively reliable data are most readily available.

Mortality risk is represented by indicators constructed from the EM-DAT, developed by the US Office of Foreign Disaster Assistance (OFDA) and the Centre for Research into the Epidemiology of Disasters (CRED) at the Université Catholique de Louvain in Brussels, Belgium (http://www.cred.be/emdat). The version of the data set used here records "natural" disasters, defined as events associated with 10 or more people reported killed, 100 or more people affected, a call for international assistance, or the declaration of a state of emergency. The data set was processed in order to remove events without a climatic component, leaving a version representing climate-related disasters only. The identification of climate-related events is discussed in Brooks and Adger (2003). The total numbers of people killed by climate-related disasters for each of the three final decades of the twentieth century were then calculated for each country represented in the database, and the results scaled by national population in order to create the risk indicators.

3.2. Vulnerability proxies: initial shortlist

On the basis of previous work and our own expert judgement, we identified a shortlist of 46 variables representing generic vulnerability, representing economic well-being and inequality, health and nutritional status, education, physical infrastructure, governance, geographic and demographic factors, agriculture, ecosystems and technological capacity. Proxy data representing each variable were acquired from a variety of sources, including the World Bank, UNDP (Human Development Index), UNEP and CIESIN. Governance data from the data set of Kaufmann, Kray and Zoido-Lobaton were used, hereafter referred to as the KKZ data set (Kaufmann et al., 1999a, b); these were augmented by data on civil and political rights from Freedom House (www.freedomhouse.org). Inevitably, the nature of the shortlist was influenced by data availability, with the variables used being acquired from data sets in the public domain. Nonetheless, the shortlist included a wide range of variables representative of the categories listed above. The shortlisted variables are detailed in Table 1.

3.3. Identifying key indicators of vulnerability

Proxy data representing the 46 shortlisted vulnerability variables were averaged over the decadal periods represented by the mortality data or, where data were unavailable for multiple years, data from a single year were used to represent an entire decade. For each proxy, a data series was constructed, in which each datum represented a specific country in a specific decade. The mortality risk proxy series was then correlated with each of the vulnerability proxy series in turn, in order to identify statistically significant relationships between mortality risk and the various socio-economic and other variables represented by the candidate vulnerability data. Significance was assessed using a Monte-Carlo randomisation procedure based on the method of Ebisuzaki (1997). This method calculates the probability that the correlation between a pair of series is exceeded when the data are randomised, while also accounting for autocorrelation in the data. Proxy data that were significantly correlated with mortality risk at the 10% level were adopted as key indicators of vulnerability.

This approach does not address the influence of hazard type, frequency and severity on mortality outcomes. If different human systems were subject to identical hazards, differences in outcome would be a result purely of variations in vulnerability across the different systems. In other words, if hazard is constant, risk is a function of vulnerability alone. However, we cannot, at the national level, examine outcomes under conditions of constant hazard, as no two countries have identical hazard profiles. Furthermore, given the high degree of geographical variation in the nature of climate hazards and the resulting difficulty in comparing "levels of hazard" across different countries, it was concluded that the development of a hazard index would be inappropriate. Physical hazard may therefore be viewed simply as an additional variable influencing mortality risk, albeit one that is not explicitly addressed in this analysis. Given that outcomes are determined by the interaction of a variety of social, economic, political and environmental factors, including the nature of the hazards associated with those outcomes, we are essentially assessing the role of the majority, rather than all, of the factors determining mortality risk. This in no way invalidates the statistical importance of the vulnerability proxies identified as significant.

3.4. Validation and interpretation of indicators through expert elicitation

Delphi surveys and iterative Delhi surveys have been used occasionally to derive quantitative estimates of elements of climate change risks and costs (e.g. Nordhaus, 1994; Vaughan and Spouge, 2002). The approach here is to utilise expert judgement as a tool for broad validation of the empirical determination of indicators outlined above.

A focus group of experts in the field of climate impacts and vulnerability, convened in August 2003 in Southampton (UK), provided weightings and interpretation of the indicators identified in the statistical analysis described above. This type of expert focus group is frequently used for the elicitation of both specific refining information and for the generation of new data and insights through direct interaction between participants (Morgan, 1996). Each expert was asked to define their area of expertise in terms of subject matter and geographical area and the results are shown in Table 2. Each participant was asked to comment from their own perspective, however broad or limited in terms of subject matter or geographical range.

Each participant was asked to consider which key indicator they felt was the "most important" in terms of defining or predicting vulnerability, and then to rank the different indicators according to importance, based on their experience in different areas of vulnerability assessment. They were given the opportunity to perform multiple ranking exercises to represent different hazards and contexts. Some participants chose to undertake separate ranking exercises for vulnerability and adaptive capacity. Participants were also asked to consider whether they felt a distinction could be made between those key indicators that represented vulnerability and those that represented adaptive capacity, and whether a distinction between vulnerability and adaptive capacity was meaningful within the context of this exercise.

3.5. Methodology for the construction of composite vulnerability indices

Those interested in the structural factors behind vulnerability for particular countries or groups of

Table 1
Potential proxies for national-level vulnerability to climate change

Category	Variable	Proxy	Source
Economy	National wealth	GDP per capita (US$ PPP)	WB
	Inequality	GINI coefficient	WIID
	Economic autonomy	Debt repayments (% GNI, averaged over decadal periods)	WB
	National wealth	GNI (total, PPP)	WB
Health and nutrition	State support for health	Health expenditure per capita (US$ PPP)	HDI
	State support for health	Public health expenditure (% of GDP)	HDI
	Burden of ill health	Disability adjusted life expectancy	WHO
	General health	Life expectancy at birth	HDI
	Healthcare availability	Maternal mortality per 100,000	HDI
	Removal of economically active population	AIDS/HIV infection (% of adults)	HDI
	Nutritional status	Calorie intake per capita	GRID
	General food availability	Food production index (annual change averaged over 1981–90 and 1991–99)	WB
	Access to nutrition	Food price index (annual change averaged over 1981–90 and 1991–99)	WB
Education	Educational commitment	Education expenditure as % of GNP	HDI
	Educational commitment	Education expenditure as % of government expenditure	HDI
	Entitlement to information	Literacy rate (% of population over 15)	HDI
	Entitlement to information	Literacy rate (% of 15–24 year olds)	HDI
	Entitlement to information	Literacy ratio (female to male)	HDI
Infrastructure	Isolation of rural communities	Roads (km, scaled by land area with 99% of population)	WB/CISEIN
	Commitment to rural communities	Rural population without access to safe water (%)	HDI
	Quality of basic infrastructure	Population with access to sanitation (%)	HDI
Governance	Conflict	Internal refugees (1000s) scale by population	WB
	Effectiveness of policies	Control of corruption	KKZ
	Ability to deliver services	Government effectiveness	KKZ
	Willingness to invest in adaptation	Political stability	KKZ
	Barriers to adaptation	Regulatory quality	KKZ
	Willingness to invest in adaptation	Rule of law	KKZ
	Participatory decision making	Voice and accountability	KKZ
	Influence on political process	Civil liberties	FH
	Influence on political process	Political rights	FH
Geography and demography	Coastal risk	km of coastline (scale by land area)	GRID
	Coastal risk	Population within 100 km of coastline (%)	GRID
	Resource pressure	Population density	CIESIN
Agriculture	Dependence on agriculture	Agricultural employees (% of total population)	WB
	Dependence on agriculture	Rural population (% of total)	WB
	Dependence on agriculture	Agricultural employees (% of male population)	WB
	Dependence on agriculture	Agricultural employees (% of female population)	WB
	Agricultural self-sufficiency	Agricultural production index (1985, 1995)	WB
Ecology	Environmental stress	Protected land area (%)	GRID
	Environmental stress	Forest change rate (% per year)	GRID
	Environmental stress	% Forest cover	GRID
	Environmental stress	Unpopulated land area	CIESIN
	Sustainability of water resources	Groundwater recharge per capita	GRID
	Sustainability of water resources	Water resources per capita	GRID
Technology	Commitment to and resources for research	R&D investment (% GNP)	WB
	Capacity to undertake research and understand issues	Scientists and engineers in R&D per million population	WB

Note: The data sources are: the World Bank (WB); Human Development Index (HDI); UNEP/GRID-Geneva (GRID); Kaufmann, Kray and Zoido-Lobaton governance data set; Center for International Earth Sciences Information Network (CIESIN) at Columbia University; United Nations World Income Inequality Database (WIID).

Table 2
Fields of expertise of the focus group participants

Expert	Hazard(s)	Context(s)
1	All	General
2	Drought, crop failure, famine	Agriculture, water resources
3	All	General
4	Floods, drought, dust, storms, sea intrusion, sea level rise	Developing countries, coastal management in the UK
5	All	Africa
6	Drought, floods	Southern Africa
7	Sea level rise, floods	UK and developing country coasts, small island developing states, coastal zones

countries should examine the scores and rankings of countries in the individual indicators. Those wishing to identify highly vulnerable countries for purposes of adaptation assistance, or as an entry point for case studies of systemic vulnerability, will find composite vulnerability indices most useful.

Caution should be exercised when interpreting the key vulnerability indicators, or when using them to construct composite vulnerability indices. Kaufmann et al. (1999a, b) discuss problems of use and interpretation for their governance indicators, for example. There is a high degree of heterogeneity in the way the KKZ data have been collected, and they are imperfect subjective measures of unobservable variables, based on a combination of surveys of business people and residents within the countries concerned and the expert judgement of individuals from outside these countries. The heterogeneity in the data means that these data sets can at best be used to place countries in groups, rather than compare governance between individual countries. Kaufmann et al. (1999a, b) also caution against averaging across proxies for a particular country, or standardising proxies. These cautionary points must be remembered when incorporating the governance data of Kaufmann et al. (1999a, b) in any composite indicator, and constitute general guidelines when using data representing such "unobservable" variables.

In order to avoid the pitfalls indicated above, a composite vulnerability index methodology was developed as follows. For each of the key vulnerability indicators, the range of data was divided into quintiles, and each country was assigned to a quintile. Where the correlation with mortality outcome was positive, a country in the bottom quintile was assigned a score of 1, and a country in the top quintile a score 5 for the indicator in question. Where the correlation with outcome was negative, the scoring system was reversed. Each country was thus assigned a score of 1–5 for each key indicator, with a score of 1 representing low vulnerability and a score of 5 representing high vulnerability. Such an approach enables an average score to be calculated across all the indicators to produce a composite vulnerability index. However, in order for the resulting index to have any meaning, we must address the issue of the relative weights of the different indicators used to produce the composite index.

3.6. Sensitivity of the composite index to different weightings

A key issue in the development of indicators is their robustness, in particular the implications of the use of different sets of weightings. While the identification of individual indicators here is based on empirical data, the analysis does not account for differences in context and process that mean certain factors (and thus certain indicators) will be more important than others in different national (and local) circumstances. The analysis performed here is designed to capture major patterns in the data, but these patterns will not be representative of all countries, or of all hazard types.

The application of subjective weightings on the one hand gives us some indication of how the relative importance of different factors might vary with context, and can also tell us how sensitive national vulnerability ratings are to perceptions of vulnerability in the expert community. The methodology used to construct the composite vulnerability index, detailed above, effectively assigns equal weights to each indicator, an arbitrary choice in terms of their relative importance. Applying weights to the individual indicators based on the strength of the statistical relationship with mortality outcome would be one way of prioritising certain variables. However, the key indicators are unlikely to be independent of each other given the nature of the shortlisted proxies, and such an approach might overemphasise the importance of factors represented by multiple related variables. Appropriate sets of weightings will also be determined to a large extent by context, and a reductionist statistical approach will not recognise this diversity in the nature of vulnerability.

In order to assess the sensitivity of country vulnerability rankings to different developmental contexts, the indicator rankings from the focus group (see above) were converted to weights, which were then applied to the key vulnerability indicators. Each set of rankings from the focus group was thus used to generate an individual composite vulnerability index, within which the country rankings were influenced by a set of subjectively derived weights. Country rankings were then compared across these different composite vulnerability indices in order to assess the impact of different weightings on the results. A mathematical index (described in more detail below) was constructed to provide a quantitative measure of the variation between different composite vulnerability indices.

3.7. Identifying the "most vulnerable" countries

Rather than simply identifying highly vulnerable countries based on their position in the equal-weights index and then assessing whether these results changed significantly as a result of different weighting procedures, we based our assessment of vulnerability on a combined assessment of country rankings in multiple composite indices constructed using a variety of weighting sets. We define significantly vulnerable countries as those that occur in the top quintile in at least one of the composite indices constructed using the different weighting sets, and the most vulnerable countries as those that occur in the top quintile for most or all of the alternative composite indices.

4. Results

4.1. Key indicators of vulnerability

The following vulnerability proxies were found to be correlated with decadal mortality outcome at the 10% significance level, and are therefore adopted as our key indicators of vulnerability:

(1) population with access to sanitation,
(2) literacy rate, 15–24-year olds,
(3) maternal mortality,
(4) literacy rate, over 15 years,
(5) calorific intake,
(6) voice and accountability,
(7) civil liberties,
(8) political rights,
(9) government effectiveness,
(10) literacy ratio (female to male),
(11) life expectancy at birth.

Indicators 1–6 are significant when tested at the 5% level, and indicators 1–3 are significant when tested at the 1% level. These indicators can be divided into three broad categories: health status, governance and education. Calorific intake and sanitation are predictive of health status, while life expectancy and maternal mortality are diagnostic of health status and of the efficacy of health care. The focus on literacy rates among the young is indicative of access to non-manual employment and to information. The governance indicators emphasise the ability of citizens to participate in the political process.

The results demonstrate that it is possible to identify key indicators of vulnerability from a suite of potentially important proxies using statistical methods. Of course these results are open to further interpretation based on the implications of the data and methodology. For example, it should be noted that many of the vulnerability proxy data are available only for a fraction of the period over which the associated mortality data are calculated. The KKZ governance data all represent 1998, towards the end of the period represented by the mortality outcome data. We might expect this to result in a decoupling of the governance and outcome data and an underestimation of the strength of any relationship between these variables, particularly if there are a number of countries where high mortality was experienced in the early or mid-1990s as a result of the occurrence of particular severe climate hazards, and where structures and institutions of governance subsequently evolved significantly over the course of the 1990s. The existence of large and significant correlations for these data suggests that there is a high degree of temporal consistency in the vulnerability proxy data, and that the assumption of relative constancy in socio-economic and political conditions over the course of a decade is a reasonable one. An analysis based on shorter timescales might be expected to indicate even stronger relationships between these variables.

Of course there are numerous examples of countries that have experienced dramatic changes in their socio-political and economic landscapes. While their number is not sufficient to completely undermine the above analysis, such discontinuities, and non-catastrophic but still significant societal change, may still obscure important relationships between the vulnerability proxy data and the mortality outcome data.

Counter-intuitively, economic indicators such as GDP and the Gini-based indicators of income inequality are not identified in this analysis as significant indicators of vulnerability. While this may, in part, be the result of pooling countries with very different socio-economic profiles, they are clearly not as useful as generic indicators as the health, literacy and governance data represented by the 11 variables listed above.

While the results of this stage of the analysis are plausible, it must be recognised that an analysis of this type is subject to many caveats and reservations, a number of which have already been mentioned. The data sample is short in duration. Data from countries of very different socio-economic characteristics and hazards profiles have been pooled. Most of the national-level indicators cannot reflect in-country variability in physical or societal space. This assessment should be seen as a first step in identifying useful proxies for vulnerability and requires verification. We present the results of one such verification exercise later in this account.

4.2. Results of focus group analysis

The areas of expertise of the focus group participants are summarised in Table 2. There was a bias towards developing country experience in the group, and towards short-term climate hazards, though not exclusively. In identifying personal areas of expertise, there was some discussion of the meaning of terms within the group. As a result, a distinction was drawn between vulnerability, which, it was agreed would, for the purposes of the focus group, be taken to mean vulnerability to short-term hazards, and adaptive capacity, which was related to the longer-term process of adjustment. It was recognised, though, that the two concepts are "difficult to disentangle". Indeed, in the rest of this paper, we tend to subsume the two into a single entity. This distinction did, however, prove extremely useful in categorising the selected indicators, as discussed below.

The specific question asked of the participants concerned which of the 11 indicators were "most important" as indicators of vulnerability at the national level. One noteworthy insight that emerged during the discussion was the association of the three indicator subsets, health, governance and education, with timescale:

> I would say they rank quite nicely because the health ones are going to be very much related to short term vulnerability. In the medium term, governance is probably the most important and the very long term, education. (Expert No. 2, agriculture and water resources focus, August 2003)

Having established that distinction between the short-term (cc. months), medium-term (cc. years) and long-term (cc. decades), with the first category related to vulnerability to short-term hazards and the latter two to adaptive capacity, there was a feeling that "you can more or less pick one out of each of those three categories" to define the most important indicators. There were distinctions drawn within each category, though, in particular, concerning indicators of causal factors and outcomes with a preference emerging for indictors linked to causation:

> Within the health category, my preference would be to go with the more fundamental causative ones rather than those which are sort of outcome indicators. So I would have thought the population would have access to sanitation and the calorie intake, one can clearly see how those are going to affect people's vulnerability, whereas the terminal life expectancy at birth are more just measures of the effect of that. (Expert No. 6, droughts and floods focus, August 2003)

Beyond that, most of the indicators were advocated by one participant or another at some point in the discussion and none was excluded as unreasonable. To determine whether or not there was a consensus amongst the group regarding the most important variables, members were finally asked to rank the different indicators according to importance, based on their experience in different areas of vulnerability assessment. They were given the opportunity to perform multiple ranking exercises to represent different hazards and/or contexts. Some participants chose to undertake separate ranking exercises for vulnerability and adaptive capacity.

Twelve sets of rankings resulted from the focus group assessment. Three of the participants addressed vulnerability and adaptive capacity separately, and two participants submitted different sets of rankings for different vulnerability hazards and contexts. One of these participants separated vulnerability rankings into those for flood hazards and those for coastal zones in general. The other submitted rankings for all hazards in one case, and specifically for the coastal zone in the other. Other participants submitted general rankings for all hazards, or specified that their responses were to be interpreted as relevant to a particular hazard or set of hazards, either generally or within a particular context.

The aggregate scores, standardised as some participants ranked a number of indicators in the same position, are shown in Table 3. Within the three categories, the key indicators, according to the focus group, are: for health, sanitation and life expectancy; for governance, government effectiveness; for education, literacy 15–24.

There was general endorsement of the indicators that had emerged from the statistical analysis:

> I see them all as proxies in a way for something vague you might call development. Developing as such isn't just a single measure, there are lots of things that contribute to it. The thing that is omitted from that group is what people regard as the most important aspect of development which is poverty but that list covers the rest of it quite well, but I think, to describe development properly which I suspect is the really critical thing, you do need at least one from each quarter. (Expert No. 4, developing countries focus, August 2003)

Not that for a country to be developed should be taken to mean that "it can automatically adapt and I've seen certainly a lot of the literature make that sort of assumption implicitly and I think that loses, if you like,

Table 3
Scores after standardising the rankings

Indicator	Score	Rank overall	Rank within category
Sanitation	0.85	3	Health 1
Literacy 15–24	0.87	5	Education 1
Maternal mortality	1.33	11	Health 4
Literacy 15+	1.08	7	Education 2
Average calorie intake	1.31	10	Health 3
Voice/accountability	0.70	2	Governance 2
Civil liberties	1.13	8	Governance 4
Political rights	0.94	6	Governance 3
Government effectiveness	0.69	1	Governance 1
Literacy ratio	1.26	9	Education 3
Life expectancy	0.85	3	Health 1

Note: A low number indicates a high preference.

the diversity and agency that people have and it constructs the developing areas as victims and I think that is very dangerous''.

4.3. Variability in country vulnerability rankings resulting from different weightings

The focus group exercise generated 12 sets of responses, each of which was associated with a set of ranks placing the 11 key vulnerability indicators in order of subjectively defined relative importance. The ''most important'' indicators were ranked as 1, the ''least important'' as 11 and equal ranks were also permitted. These ranks were then converted to weights. A rank of 1 was assigned a weight of 11, a rank of 2 a weight of 10 and so on. For each response, a composite index of vulnerability and/or adaptive capacity was constructed. The country scores for an individual indicator (ranging from 1 to 5) were multiplied by the weight assigned to that indicator. A country's score in the composite index was then calculated as the mean of the weighted scores which span the range from 1 to 55.

The result of this exercise was 13 alternative composite indices of country-level vulnerability (including the equal-weights index). An initial assessment of variability in country rankings across these indices was performed by plotting the mean rank of a country in all 13 indices against the difference between its highest and lowest rank (Fig. 1). A small number of countries exhibit very large variations in rank, exceeding 100 places. However, most countries vary in rank by less than 50 places across the various indices, with a large number varying by fewer than 25 places, or some 12% of the possible range (out of a total of 205 countries represented).

In order to assess the divergence between the various composite indices constructed using different sets of weights, we calculated the average difference ∂ in

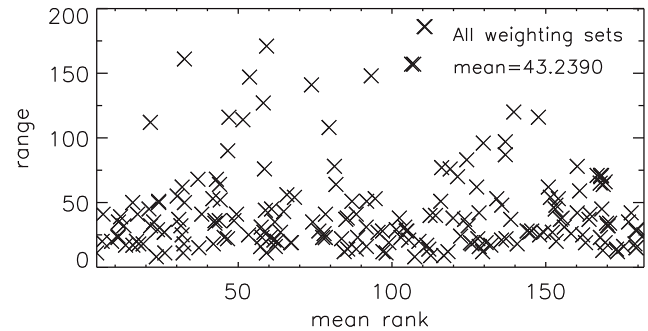

Fig. 1. Sensitivity of individual country rankings to different weightings of individual indicators.

country rankings between pairs of composite indices:

$$\partial_i^{m,n} = \left(\sum |r_i^m - r_i^n|\right)/N,$$

where r_i^m is the rank of country i in index m, and N is the number of countries represented in each index (in this case 205). With 13 indices (including the equal-weightings index), there are 78 possible pair combinations; the 78 corresponding values of ∂ range from 4 to 26. The greatest value of ∂ occurs between indices 3 and 12, constructed from sets of weightings chosen to represent adaptive capacity with respect to drought, crop failure and famine, and vulnerability to sea level rise within the context of small island developing states and coastal zones, respectively. The smallest value of ∂ occurs between indices 5 and 13, representing generalised adaptive capacity and generalised, aggregated vulnerability and adaptive capacity, respectively. Fig. 2 shows the ranks in index 3 plotted against those of index 12 (most dissimilar indices) and ranks in index 5 plotted against those of index 13 (most similar indices). In the former case, the majority of countries and territories exhibiting large differences in rank are associated with missing data in a number of categories represented by the 11 constituent variables. Many of these are small island states or territories.

Fig. 2 illustrates that there is a degree of consistency in terms of country rankings between the different indices, even where the results are most divergent. However, assessments of vulnerability or adaptive capacity based on individual country rankings are generally not appropriate, due to the variation in rank across indices and for reasons discussed above. A more appropriate method of assessment is one based on placing countries in vulnerability categories, for example as represented by quintiles of country scores or rankings. Here we divide the rankings into quintiles to produce categories containing equal numbers of countries, across all indices. A further test of robustness across different sets of weightings is the extent to which countries fall consistently in a particular quintile, or vulnerability category, across the different indices. Fig. 3

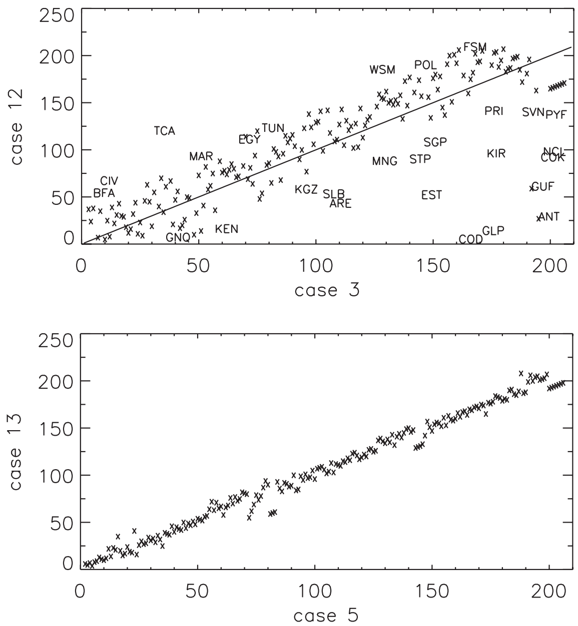

Fig. 2. Scatter plots of country rankings for the indices with the greatest (top) and least (bottom) divergence, measures in terms of the mean difference in individual country rankings or 'distance', ∂.

shows the % of countries common to the top quintile of the constituent indices of each possible index pair, plotted against the corresponding value of ∂. In most cases, over two-thirds of the countries represented in the upper quintiles of a pair of indices are common to both indices.

4.4. Identification of the "most vulnerable" countries

While there is variation between composite indices according to the weightings assigned to the variables from which they are constructed, the distribution of country scores is not systematically and radically different, suggesting that the indices are relatively robust in their representation of vulnerability, yet sensitive enough to emphasise its different aspects. Countries that score consistently highly, i.e. that occur in the upper quintile of multiple indices, may be interpreted as being highly, and systematically, vulnerable within the framework considered here (i.e. one that emphasises human mortality). Table 4 lists the countries occurring in the upper quintiles of any of the 13 indices, along with the number of occurrences. We define countries occurring in the upper quintile of one or more index as moderately to highly vulnerable, and those occurring in the upper quintile of 11 or more of the 13 indices as the "most vulnerable" countries. The most vulnerable countries are nearly all situated in sub-Saharan Africa: of the 59 countries and territories listed in Table 4, 33 are sub-Saharan African nations, five are small island states or territories and many have recently experienced conflict.

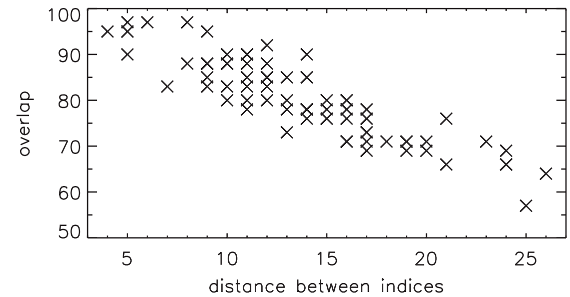

Fig. 3. Overlap between upper quintiles of indices constituting each of the 78 possible index pairs (% of countries occurring in both indices for each pair, plotted against mean difference in rank or 'distance' between pairs, ∂).

Table 4
Countries whose rankings occur in the upper quintile of multiple vulnerability indices (from a total of 13 indices) constructed from different sets of weightings of constituent variables, with the number of indices for which they occur in the upper quintile

Most vulnerable countries		Moderately to highly vulnerable	
Afghanistan	13	*Cote d'Ivoire*	10
Angola	13	Qatar	10
Burundi	13	*Kenya*	9
Central African Rep.	13	Laos	9
Democratic Republic of Congo	13	North Korea	8
Eritrea	13	Yugoslavia	7
Ethiopia	13	*Nigeria*	7
Equatorial Guinea	13	*Benin*	6
Gambia	13	**Turks and Caicos Islands**	6
Guinea Bissau	13	Bosnia Herzegovina	5
Haiti	13	*Congo*	5
Mauritania	13	*Mali*	5
Mozambique	13	**Guadeloupe**	5
Niger	13	*Senegal*	5
Pakistan	13	**Tonga**	5
Rwanda	13	Nepal	4
Sierra Leone	13	*Djibouti*	3
Somalia	13	*Zimbabwe*	3
Sudan	13	Azerbaijan	2
Togo	13	Puerto Rico	2
Turkmenistan	12	Bangladesh	1
Chad	12	Bhutan	1
Gabon	12	Estonia	1
Iraq	12	Cambodia	1
Liberia	12	*Uganda*	1
Malawi	11	United Arab Emirates	1
Brunei Darussalam	11	French Guiana	1
Burkina Faso	11	Morocco	1
Guinea	11	**Wallis and Futuna Islands**	1
Yemen			

Note: Countries in continental sub-Saharan Africa are highlighted in red, small island states or territories in blue.

The results in Table 4 are broadly consistent with subjective expectations, with the possible exception of the presence of Estonia, Brunei Darussalam and Qatar. Bangladesh is less vulnerable than might be expected according to this analysis, although the factors leading to large negative outcomes from climate-related disasters in Bangladesh are as much geographical as social and political, and may therefore be under-represented by the indices used here. Furthermore, high mortality is indicative of high risk, which is determined by levels of climate hazard as well as socio-economic vulnerability; countries such as Bangladesh may be subject to high outcome risk as a result of exposure to very high levels of hazard or event risk, even if their vulnerability is relatively low when compared with other countries subject to less significant hazards. A death toll of 138,000 from a tropical cyclone in 1991 was followed by hugely reduced mortality from a similar event in 1997, suggesting that Bangladesh has addressed its vulnerability with some considerable success. According to Alam (2003), "Bangladesh has set a pioneer example in disaster management during the cyclones of 1991 and 1997. The role of the government and non-government organizations during the pre and post disaster periods helped shrink the number of deaths and damage. The initiatives were appreciated and recognized worldwide."

The vulnerability of small island states is likely to be under-represented as they constitute a minority "special case"; the particular factors that lead to large negative outcomes in islands (small size, low elevation, isolation, etc.) are not characteristics of the majority of the countries assessed here, and their effects will therefore not lead to a significant statistical signal in the analysis. However, countries that are exposed to frequent severe climate extremes are likely to be more prepared than those that are not, and are likely in many cases to have reduced their vulnerability through adaptation to recurrent climate hazards. It is perhaps worth reiterating here that vulnerability as defined and assessed in this study only leads to severe negative outcomes when coupled with climate hazards; conversely, relatively low vulnerability is no guarantee of safety when it is countered by extremely high levels of hazard. The purpose of this study is to develop a method for identifying vulnerability even where it is not thrown into sharp relief by frequent and severe extremes, an exercise that is particularly useful when we are considering the potential impacts of climate change, which is likely to lead to the emergence of new hazards, associated with changing patterns of climate-related risk.

5. Discussion

We have identified 11 key indicators of vulnerability, broadly defined as integrated over time and incorporating elements of adaptive capacity. The results from the focus group exercise emphasise the importance of governance indicators (voice and accountability and government effectiveness), sanitation and life expectancy. The participants broadly agreed that the indicators could be separated into variables that were essentially indicators of instantaneous vulnerability (i.e. at the time of onset of a hazard event), and those that represented the capacity to adapt over time. The exercise emphasised the importance of governance, civil and political rights, and literacy as indicators of adaptive capacity. It is notable that GDP is not identified as a significant indicator of vulnerability. This does not indicate that poverty is unimportant in determining vulnerability, rather that GDP does not capture the aspects of the economic environment that make people vulnerable. Nonetheless, all the indicators presented here are likely to be jointly determined, and related to indicators not significantly correlated with mortality outcomes; in other areas of research, for example, human capital and economic growth have been shown to be intimately related (Krugman and Venables, 1995; Knack and Keefer, 1997). While national economic wealth plays a key (but not exclusive) role in shaping the developmental environment, it appears that non-economic indicators are more directly representative of the vulnerability of national populations in terms of mortality associated with climate-related hazards.

As the indices developed here are based on indicators of vulnerability related to mortality outcomes, the indicators of adaptive capacity represent the capacity to reduce mortality from climate hazards, and should be used within this context. They may be less appropriate for assessing economic vulnerability, or for identifying the factors that enable societies to ameliorate non-fatal outcomes. The implicit adaptation goal, built in to this analysis, is one of reducing mortality outcomes from climate-related disasters (Haddad, 2005).

This analysis indicates that reductions in mortality outcomes may be achieved through increasing government effectiveness and accountability, civil and political rights, and literacy. While these factors mask the more complex processes that lead from climate hazards to high mortality, they also underlie them. A literate population will be better able to lobby for political and civil rights, which in turn will allow it to demand accountable and effective government. Where such rights exist, governments are more likely to become accountable for reducing the impact of successive high-mortality disasters, and are thus more likely to address vulnerability (Wisner et al., 2003).

It is interesting to compare the 11 key indicators with other indicators developed for sub-national scale contexts. The World Food Programme uses indicators representing the following variables to assess vulnerability to food insecurity in Kenya at the district level (Haan et al., 2001):

Life expectancy	Mean vegetation
Adult literacy	Vegetation variation

Stunting	Education
Wasting	Gender development
Livelihood diversification	Non-agricultural income
Access to safe water	Proximity to markets
Livelihood fishing	HIV/AIDS incidence
High potential land	Civil insecurity

Some of these indicators are identical to those identified in the analysis described in this paper, and indicators of health, education and governance (in the form of security) are represented in both sets. The sub-national WFP indicators also include variables specific to the local context, representative of livelihoods and environmental conditions. These contextual indicators are extremely important for the natural resource dependent communities with which the WFP is concerned in this case, but are not universally relevant, and would be inappropriate or meaningless in certain other contexts. This comparison of indicator sets across scales demonstrates that, while the national-level indicators presented in this paper capture certain important elements of vulnerability operating at the scale of the nation state, for a full description of vulnerability sub-national scale factors representing local contexts must also be considered.

The results confirm the vulnerability of sub-Saharan Africa, with this region making by far the largest contribution to the set of highly vulnerable countries. Not only does environmental stress make countries prone to conflict (see e.g. Stewart, 2002), but conflict exacerbates vulnerability and reduces the adaptive capacity of a country and its population to deal with environmental stress. Research on the causal mechanisms between conflict and vulnerability suggests that it is the lack of functioning government, the breakdown of common management institutions and direct impacts of conflict on health and well-being that undermine the capacity to adapt (Barnett, 2005). Many of the most vulnerable countries, notably including nations outside of sub-Saharan Africa such as Iraq and Afghanistan, were experiencing or recovering from conflict during the period represented by the data.

6. Conclusions

This paper has presented a novel methodology for assessing vulnerability to climate-related mortality, based on empirical analysis rather than subjective identification of indicators, and which addresses the sensitivity of vulnerability assessments to different sets of subjective weightings. Our approach provides a firmer foundation for the identification of highly vulnerable countries than a simple equating of vulnerability with poverty, and offers a robust methodology for the assessment of vulnerability that is not based on a single, subjective index.

The results of this study confirm the extreme vulnerability of sub-Saharan Africa, although the nature of the analysis probably results in the vulnerability of small island states being underestimated. While the results broadly support existing views of vulnerability, they produce some unexpected results, such as the absence of GPD from the list of key indicators, the relatively low vulnerability of Bangladesh, and the relatively high vulnerabilities of some wealthier nations. These findings in particular suggest potential avenues for research that may further enhance our understanding of vulnerability.

The results from the analysis presented here, and their interpretation, highlight some of the caveats that must be borne in mind when using spatially and temporally aggregated data. Within countries, vulnerability is geographically and socially differentiated, and processes that mediate the outcomes of hazard events operate at the local scale. Ultimately, it is people not countries that are vulnerable. National-level indicators must therefore be complemented by locally contextual indicators to yield a full picture of vulnerability. The analysis presented here can provide information regarding leverage points in a country's institutional environment for the promotion of resilience, but must be complemented by studies of the distribution of vulnerability, including the identification of vulnerability "hotspots". Prospects for adaptation will be improved by addressing issues of health, education and governance, but specific measures and technologies for the promotion of adaptation will also be required. The nature of these measures and technologies will be determined by local contexts, and they should be targeted at specific localities, groups and sectors.

The results of this analysis are important in that they provide an empirical basis for assessing vulnerability rather than risk; adaptation through vulnerability reduction is of particular relevance where climate projections are unavailable or where such projections are associated with a high degree of uncertainty, for example in monsoon regions in sub-Saharan Africa (Brooks, 2004; Conway, 2005).

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