ELSEVIER

Environmental Hazards 7 (2007) 20–31

ENVIRONMENTAL HAZARDS

www.elsevier.com/locate/hazards

Papers

Risk and vulnerability indicators at different scales: Applicability, usefulness and policy implications

Joern Birkmann*

United Nations University, Institute for Environment and Human Security (UNU-EHS), UN Campus, Hermann-Ehlers-Street, 10, 53113 Bonn, Germany

Abstract

This paper outlines selected approaches to measuring risk and vulnerability to hazards of natural origin using indicators and indices. It discusses their applicability, usefulness and policy implications. Indicators and indices have been developed on different scales and for different purposes. The paper will briefly introduce three global approaches to disaster-risk identification and will juxtapose them with one local approach in order to examine the differences concerning the functions and the purpose of the assessment as well as their impact for policy development. In contrast to an earlier comparative analysis of the three global disaster-risk indicator programmes by Mark Pelling in 2004, which focused primarily on the methodologies used, this paper places more emphasis on aspects of applicability and policy implications and outlines challenges and limitations of the different approaches. Since the assessment and mapping of human vulnerability is less developed than hazard assessment work [Pelling M., 2004. Visions of Risk: A Review of International Indicators of Disaster Risk and its Management. UNDP—Bureau for Crisis Prevention and Recovery (BRCP), Geneva], this paper focuses in greater depth on how the approaches capture vulnerability. Conclusions will be formulated on how to further enhance vulnerability identification, particularly at the sub-national level.

Keywords: Risk; Vulnerability; Indicators; Natural hazards; Review risk indicators

1. Introduction

Disasters, such as the Indian Ocean Tsunami in December 2004, Hurricane Katrina and the Pakistan Earthquake in 2005, attract a great deal of attention in the media and in the disaster-assistance community. Focusing on disasters after they occur is essential from a humanitarian point of view, but not sufficient for reducing their tragic consequences to people, economies and the environment. Identifying and measuring risks and vulnerabilities before a disaster occurs—and also after disasters have happened—are essential tasks for effective and long-term disaster-risk reduction. In this regard, 'measuring vulnerability' is not limited to quantitative approaches; rather, it encompasses both quantitative and qualitative methods to describe and operationalise vulnerability (see in detail Birkmann and Wisner, 2006). The international community has established global disaster response mechanisms, such as the instruments of Flash Appeals within the UN system (e.g. after the Indian Ocean Tsunami). In contrast, the development of a common methodology to identify and measure risk and vulnerability to disasters in order to define disaster-risk management and disaster-relief priorities is still not sufficiently developed. Enhancing disaster-risk reduction before a disaster occurs, and also during the reconstruction process, requires enhanced knowledge regarding the most vulnerable groups, the areas at risk and the driving forces that influence and generate vulnerability and risk (see e.g. Bogardi and Birkmann, 2004).

In recent years, an increasing number of global and local initiatives have been launched to measure risk and vulnerability with a set of indicators and indices (Birkmann, 2006). This paper reviews four attempts to measure risk and vulnerability by applying indicators.

The selection of the approaches was based on the intention to analyse different quantitative approaches at

*Tel.: +49 228 815 0208; fax: +49 228 815 0299.
E-mail address: Birkmann@ehs.unu.edu

1747-7891/$ - see front matter © 2007 Elsevier Ltd. All rights reserved.
doi:10.1016/j.envhaz.2007.04.002

various levels aiming to measure risk and include vulnerability as a sub-component. Although vulnerability is a key issue in understanding disaster risk (Cardona, 2005, p. 57), vulnerability assessment and quantification is often less advanced than hazard mapping and quantification. Therefore, this paper concentrates particularly on aspects of how these approaches capture vulnerability as a sub-component of risk.

All approaches presented in this paper are based on a common theory that disaster risk is a product of three major elements: exposure to hazards, the frequency or severity of the hazard and the vulnerability. Moreover, all the approaches aim to measure risk and vulnerability through selected comparative indicators in a quantitative way in order to be able to compare different areas or communities (see in detail Bollin and Hidajat, 2006; Dilley et al., 2005; Peduzzi, 2006; Cardona, 2005). These similarities make an analysis of the approaches interesting and useful.

Furthermore, important international efforts are being prepared to downscale global indexing programmes to the national and sub-national levels (see GRIP website, 2006). This paper is intended to contribute to the discussion, since it also examines the potential of the up- and downscaling of approaches and selected indicators as well as the problem of 'contextualisation' (adjustment to the specific situation of a region, country or community). Additionally, the approaches presented are subject of on-going discussion and development; therefore, the author sees them as a process rather than a final product. This means that thoughts on how to improve and further develop these approaches are an important issue. Lastly, other initiatives can also learn from these approaches, their challenges and critical review.

2. Vulnerability and risk

Many diverse research and policy communities, including those pursuing issues of global environmental change, food security, development assistance and disaster risk, have developed definitions and pre-analytic visions of risk and vulnerability. While in the '70s and early '80s vulnerability was often associated with physical fragility (e.g. the likelihood of a building to collapse due to the impact of an earthquake), today the concepts of vulnerability go far beyond the likelihood of collapsed physical structures (see e.g. Bankoff et al., 2004).

United Nations/International Strategy for Disaster Reduction (UN/ISDR), for example, defines vulnerability as the "*conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of a community to the impact of hazards*" (UN/ISDR, 2004). According to this definition, the hazard event itself is viewed primarily as external to the system or element at risk, and the term vulnerability describes the conditions of a society or element at risk that also determine the potential or revealed hazard's impact in terms of losses and disruption. Since risk is generally defined as the product of the hazard probability and its consequences, risk can be viewed as a function of the hazard event and the vulnerability of the elements exposed.

Vulnerability is often viewed as an intrinsic characteristic of a system or element (UN/ISDR, 2004; Cardona, 2004, p. 37; Wisner, 2002, pp. 12/7; Thywissen, 2006), although most analysts acknowledge that vulnerability is conditional on a hazard, e.g. with respect to its frequency and severity, or that it is useless to discuss vulnerability independent of its hazard context. Wisner (2002) underlines that difficulties in recovering from the negative impacts of hazardous events are also part of vulnerability; thus coping and recovery must be part of its assessment. This dualistic understanding of vulnerability, which encompasses susceptibility—understood as characteristics which describe the weakness of a system or element exposed—on the one hand, and coping capacities—positive resources to deal with the negative impacts of a hazardous event and its impacts—on the other, underlies many vulnerability approaches, e.g. Wisner (2002) and—to a certain extent—Bohle (2001). An additional extension of the concept can be seen in the shift from the dualistic structure to a multi-faceted structure. For example, within the discourse on vulnerability in the global environmental change community, vulnerability not only captures susceptibility and coping capacity, but also adaptive capacity, exposure and the interaction with perturbations and stresses (see Turner et al., 2003).

Overall, the concept of vulnerability has been continuously widened and broadened towards a more comprehensive approach encompassing susceptibility, exposure, coping capacity and adaptive capacity, as well as different thematic areas, such as physical, social, economic, environmental and institutional vulnerability (see Fig. 1 and in detail Birkmann, 2006). The different views of vulnerability are also visible within the approaches examined in this paper.

3. Global and international Disaster-Risk Index projects

Within the last few years, three major global projects have been carried out to measure risk and/or vulnerability with the help of indicators and indices at the national scale, and for international and global comparisons. These include the UNDP's Disaster Risk Index (DRI) (UNDP, 2004), the Hotspots project by Columbia University (see Dilley et al., 2005) and the Indicators for the Americas developed by the Institute of Environmental Studies, National University of Colombia—Manizales (see Cardona, 2005). This paper does not intend to present the methodology of these approaches in detail; rather, it examines the approaches from the point of view of their intended goals and functions as well as their measurement of vulnerability. Moreover, the issues of up- and downscaling, the contextualisation (adjustment to the specific situation of the country or target group) and the policy relevance of the approaches will be discussed.

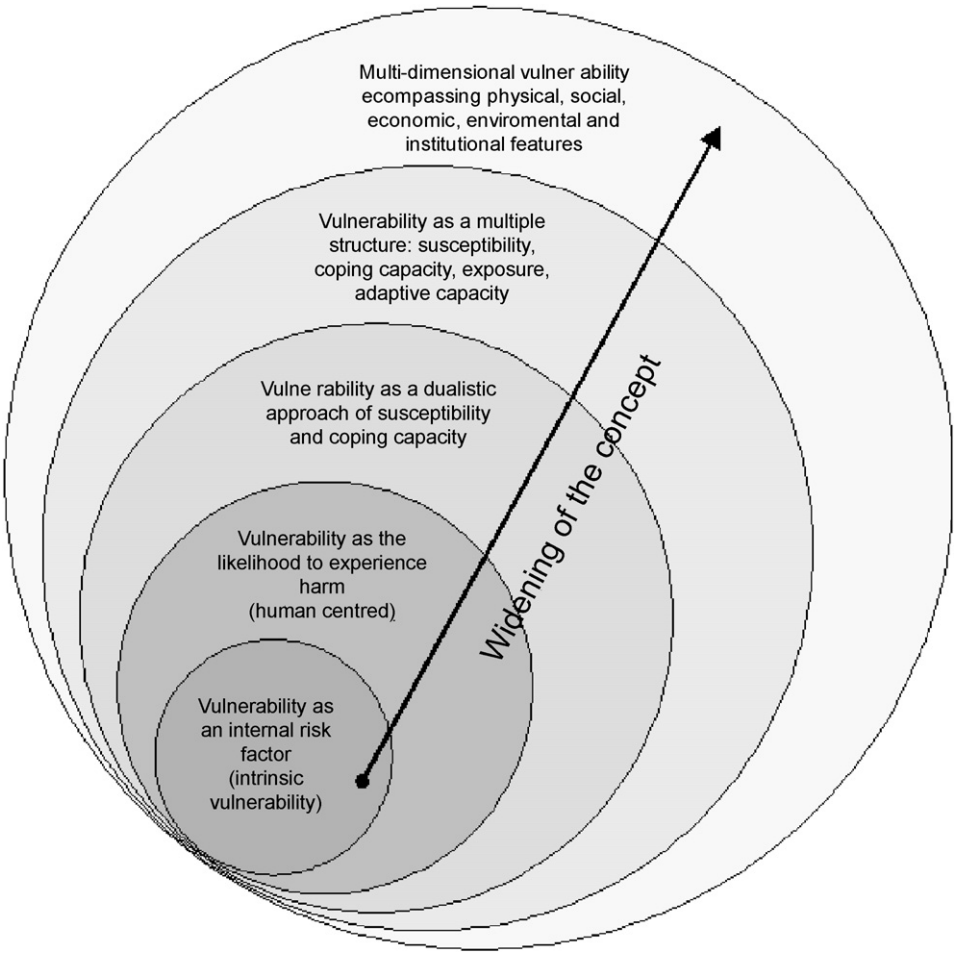

Fig. 1. The spheres of vulnerability. *Source*: Birkmann (2005).

3.1. The Disaster Risk Index

The authors of the DRI aimed at creating a quantitative measure that would allow for comparison of disaster risk between countries exposed to selected hazards. Although disaster impacts can vary from hazard to hazard, it was important for the developers of the approach to select key indicators that would be useful in comparing disaster risk between countries and also between hazard types. Beside this, the DRI was developed in order to outline the relationship in which development influences disaster risk and vulnerability (UNDP, 2004). This means that the findings of the DRI project should particularly enable the measurement and comparison of relative levels of physical exposure to hazards, vulnerability and risk between countries, as well as the identification of vulnerability indicators (UNDP, 2004, p. 2).

Following this intention, the DRI Index is based on mortality data, since in this perspective one person killed by a cyclone is comparable to one person killed by a flood or landslide. The DRI is calculated for floods, tropical cyclones and earthquakes and has global coverage but with nation–state resolution. Within the framework of the DRI, vulnerability is seen as a factor that explains why people with the same level of physical exposure to natural hazards can be more or less at risk, or have been faced with higher or lower fatalities over the last few years due to hazards of natural origin (Peduzzi, 2006).

As a first estimation, the DRI calculates what is termed the 'relative vulnerability' of a country to a given hazard, which is generated by dividing the number of people killed by the number of people exposed (see Fig. 2). Exposure (physical exposure) is measured as the number of people located in areas where hazardous events occur combined with the frequency of the hazard events in question (UNDP, 2004, p. 31). According to this approach, a higher relative mortality, expressed by average annual deaths in proportion to average population exposed, indicates a higher vulnerability for a particular country. Thus, countries suffering higher losses of lives than others equally exposed have a higher relative vulnerability (Dilley, 2005).

For example, as shown in Fig. 2, China and India face a high number of average annual deaths due to flooding, and these countries are at the same time the highest in the world in terms of populations exposed. This means they are moderately vulnerable. By contrast, Venezuela, Afghanistan and Somalia are countries with a high relative vulnerability to floods.

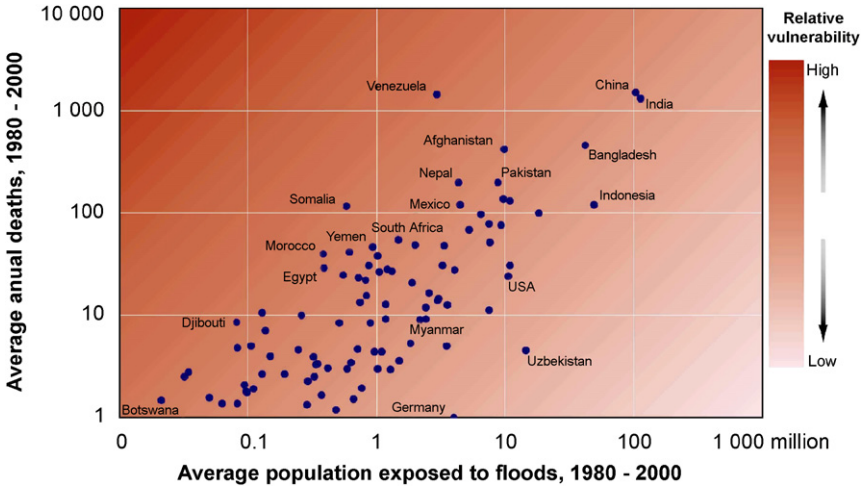

Fig. 2. Relative vulnerability for flooding, 1980–2000. *Source*: EM-DAT OFDA/CRED and UNEP/GRID-Geneva (in UNDP, 2004).

As a second measure of vulnerability, the authors use multiple-regression analysis to determine factors that best explain the recorded mortality within a country attributable to specific hazards. In addition to physical exposure, the analysis revealed that, for floods especially, a low per-capita Gross Domestic Product (GDP) (poor nations or least developed countries) and also low density of population (rural areas/regions) characterise countries that are highly vulnerable to and most at risk from floods (UNDP, 2004, p. 42). The approach is based on EM-DAT data generated and gathered by Center for Research on the Epidemiology of Disasters (CRED), covering a timespan of about 20 years.

3.1.1. *Discussion: applicability and usefulness*

Overall, the approach can be applied globally. This means that the applicability of relative vulnerability measures worldwide is proved to be possible. At the same time, however, characterising vulnerability along only one dimension (mortality) is problematic. In many regions, floods, for example, occur regularly and catastrophically without significant loss of life, but with very significant loss of property and livelihoods, as seen in Serbia or Rumania in April 2006 (see e.g. SCSP, 2006). Many of these local villages suffer extreme poverty and are highly exposed. However, according to this analysis, these areas do not show up as highly vulnerable to floods, since the floods did not cause major fatalities.

Additionally, the analysis suffers from (1) the fallacy of averaging across extremes during a short time period and (2) the fallacy of not taking into account the heterogeneity of extremes. Floods and other extreme events cannot be meaningfully averaged over a two-decade period. Such long-tailed, high-impact events may occur only once in a hundred years. There could be radical shifts in the classification of a country's relative vulnerability due to the occurrence of one major event without any changes in the underlying drivers of vulnerability. However, other approaches also have to deal with these problems, particularly if they aim to compare risk and vulnerability between areas and countries. Furthermore, the 'physical exposure' definition employed also includes the 'frequency' of hazardous events; this means that the vulnerability assessment (see Fig. 2) shifts towards risk assessment.

The usefulness of the approach has to be discussed regarding its goals and functions, e.g. the goal of the approach is to outline the link between disaster risk and development, while one major function of the approach is to visualise the distribution of risk and human vulnerability globally between countries (function comparison).

It is important to acknowledge that the DRI assessment revealed enormous differences between the disaster risk of the least developed countries and of highly developed countries (Peduzzi et al., 2005). On the other hand, more in-depth research is needed to examine the various linkages between different forms of development and disaster risk and vulnerability. Especially processes that contribute to higher levels of vulnerability of different social groups or economic sectors require sub-national and local assessment approaches. The regression study undertaken within the approach can provide insights into the factors that contribute to the likelihood of a person being killed due to natural hazards; however, it cannot shed light on the underlying vulnerability issue. In this context the approach does not seem to fulfil its stated purpose, which is to explain why people with the same level of exposure can be more or less at risk.

3.2. *The Hotspots Project*

The Hotspots Project is carried out primarily by Columbia University in co-operation with the World Bank and other institutes (see Dilley et al., 2005). The idea was to develop a world map of hotspots, i.e. a global map showing where the risk of mortality and economic losses due to hazards of natural origin are greatest. This approach thus

focuses foremost on risk as a product of hazard frequency and consequence.

The goal of the Hotspots Project is to provide insights about disaster-risk patterns in order to improve disaster preparedness and the prevention of losses. The study aimed at identifying global hotspots of risk by comparing risk levels—regarding individual and multi-hazard risks—across countries and regions. The identification of hotspots should support the definition of priorities regarding risk-management efforts and should draw attention to areas where risk management is most needed. Additionally, Hotspots focused on the assessment of different data sets and methodologies for risk identification and assessment (see in detail Dilley et al., 2005; Dilley, 2005).

The global risk analysis was carried out for earthquakes, volcanoes, landslides, floods, drought and cyclones. In contrast to the DRI, the spatial resolution of the Hotspots Project focused on grid cells (grid cells $2.5 \times 2.5\,km^2$), which allow for the analysis of risk at a sub-national level.

In addition to estimating risks in terms of disaster frequency, mortality and economic losses, the Hotspots assessment attempts to give some indication of vulnerability by comparing estimated risks in relation to the exposure to hazardous events (gridded population) and the elements at risk (approximated by GDP per unit area). Compared to the 'Relative Vulnerability Index' of the DRI, the Hotspots Project encompasses three main indicators focusing, on the one hand, on mortality-related risk, and additionally on the total and relative economic losses, calculated as the risk of direct economic losses expressed as a proportion of GDP. The Hotspots study does not explicitly measure vulnerability. However, its approach to calculating risk underlines the view that vulnerability is associated with human and economic losses. In this context, account was taken in particular of fatalities and direct economic losses, based on historical disaster-mortality and economic loss rates for 28 groups of regions and country-wealth classes for each hazard type (Pelling, 2004). Besides focusing on revealed vulnerability in terms of fatalities and economic losses, the approach defines vulnerability levels for different areas based on the income classes used by the World Bank (see Dilley et al., 2005; Chen, 2006).

Similar to the DRI, the Hotspots approach is based on a relative vulnerability and risk estimation; this implies that the total number of grid cells is divided into deciles, ten groups of approximately equal number of cells based on the value of each individual hazard.

Fig. 3 shows the distribution of risk of economic loss due to floods as a proportion of GDP. The map underlines that the relative economic losses due to floods were particularly severe in the last 20 years in Asia (particular southern China), South-East Asia and Eastern Europe and some Caucasus regions. Consequently, these areas are at higher flood risk, which might be explained by more intense and frequent floods, by the degree of vulnerability, or both. Areas with very low population densities (less than 5 persons per square km) were excluded (see in detail Dilley et al., 2005, p. 27).

3.2.1. *Discussion: applicability and usefulness*

In contrast to the DRI 'relative vulnerability' measure and risk calculation, the Hotpots approach introduces absolute and relative economic losses as a proportion of GDP. Moreover, the hotspot approach visualises risk information at a relatively fine spatial resolution (grid cells $2.5 \times 2.5\,km^2$) (see in detail Dilley et al., 2005), which means that results show sub-national distribution patterns of risk within a country. This is especially interesting in large countries such as China and the US. On the other hand, this approach and its applicability in the current form relates mainly to the global level. Even though it is possible to conduct Hotspots analyses at the sub-national level in some countries, it does not allow full coverage of countries with low-density population since these areas are excluded from the survey. This exclusion of areas with very low population densities is a clear disadvantage, since the DRI multiple-regression analysis underlined, for example, that the relative flood mortality is higher in less populated than in densely populated countries.

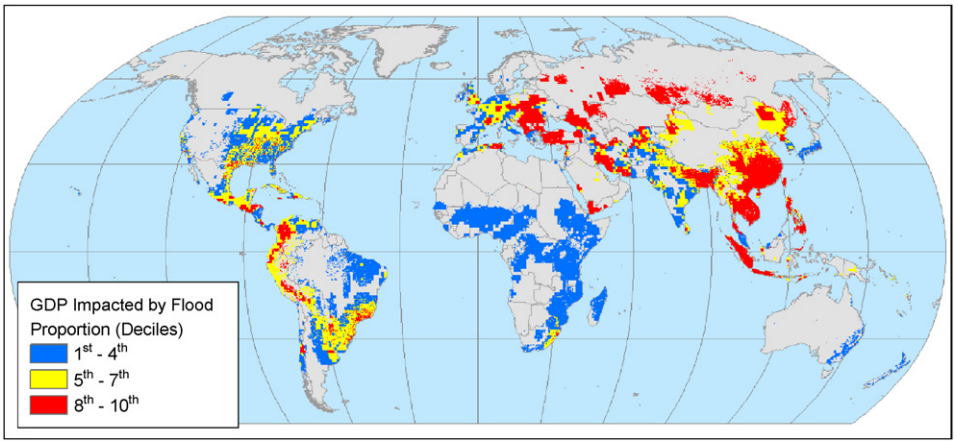

Fig. 3. Global distribution of risk of economic loss due to floods as a proportion of GDP. *Source*: Dilley et al. (2005).

Hence, some low-density population areas might be local and sub-national hotspots for mortality-related risk and thus the most vulnerable, since disaster-management capacities are generally lower than in highly urbanised areas. Overall, the approach offers interesting insights into the global distribution of absolute and relative economic risk as well as mortality risk in respect of different hazards and can identify regions most at risk in the past and today based on a limited set of indicators.

3.3. The Americas project

The Americas Indexing Programme was carried out by the Institute of Environmental Studies, National University of Colombia—Manizales, in co-operation with, and for, the Inter-American Development Bank (Cardona, 2005). The purposes of the assessment are (1) to assist policy makers in identifying investment priorities to reduce risk, (2) to identify national risk-management capacities and evaluate the effects of policies and investments on risk management, (3) to promote the exchange of information, and (4) to gauge a country's relative position and compare its evolution over time.

In contrast to the global disaster-risk indexing approaches presented above, this approach covers vulnerability and risk with more indicators and aims to provide a more disaggregated and holistic view. The approach encompasses four main indices: the Disaster Deficit Index (DDI), the Local Disaster Index (LDI), the Prevalent Vulnerability Index (PVI) and the Risk Management Index (RMI) (see in detail Cardona, 2005, 2006a). The approach was applied to 12 countries in Latin America and the Caribbean, aiming at supporting and informing national decision-makers. Each index is composed of a number of indicators and sub-indices; thus the approach includes a total number of more than 50 indicators. The following review focuses on the PVI and the RMI, since these are most relevant for measuring vulnerability. However, the Americas Indexing Programme encompasses more useful indicators within the DDI and LDI (see in detail Cardona, 2005); which are not taken into account in this review, since the major emphasis is given to aspects of vulnerability.

The PVI views vulnerability as inherent to the system and independent of the hazard. The different dimensions of the PVI are calculated from eight quantitative components, which in some cases already imply highly aggregated data. The index provides information for three sub-categories of vulnerability: (a) exposure (e.g. population density, capital stock and investment) and physical susceptibility, (b) socioeconomic fragility (e.g. poverty, inequality, unemployment and debt), and (c) lack of resilience (e.g. human development, social expenditures on pensions, television sets and hospital beds) (see Cardona, 2005, p. 12). The results of the application of the index in Latin America and the Caribbean indicate that Jamaica, Guatemala and El Salvador are highly vulnerable, while Guatemala is also indicated as the country with the lowest resilience (Fig. 4).

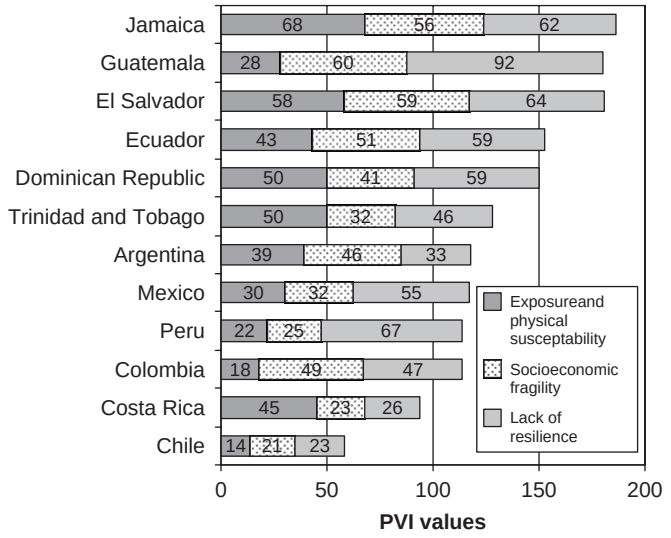

Fig. 4. Socioeconomic vulnerability in the Americas, 2000. *Source*: figure according to Cardona et al. (2004).

In contrast to the DRI and Hotspots approaches, this concept encompasses an index to measure the 'risk-management performance' of a country with respect to policy measures undertaken to reduce disaster risk. The RMI is based on six qualitative components, which were evaluated by experts in each country. The risk-performance evaluation shows Chile with high scores, while, by contrast, the Dominican Republic and Ecuador were judged to have the weakest risk-management performance.

3.3.1. Discussion: applicability and usefulness

The Americas approach provides a great deal of comparative information on many aspects of disasters, risk and vulnerability in Latin America and the Caribbean, and, consequently, is a valuable resource. The selection and aggregation of this information, however, raises difficult issues of specification and in some cases of weighting. Are the specified indicators the main explanatory variables influencing risk and vulnerability, and can these indices be weighted into a composite index? A look at a number of indicators raises doubts on the question of specification. For example, does an increase in a country's assets and investment—such as represented through the 'gross domestic fixed investment (in % of GDP)'—lead to increased or decreased vulnerability? On the one hand, exposure and expected losses increase with increasing capital. On the other hand, rich societies experience higher absolute capital loss but far less economic loss as a proportion of GDP (see in detail Dilley et al., 2005, p. 71) and fewer fatalities from disasters. Do social expenditures on pensions, health and education increase resilience? This can be an appropriate indicator for most developing countries and some countries in transition; however, for other countries—especially countries in Central Europe such as Germany—this

aggregated indicator might have a reverse meaning. Although this specific approach is not aiming to create a universally valid indices system, it is interesting to explore whether the same indicators can have different meanings in different contexts. For example, high and increasing levels of expenditures on pensions, health and education—used to measure 'increasing resilience' in the Americas Project—would not be applicable to the German situation. Since the nation has a serious problem with an ever-ageing population and a declining number of people of working age, rising costs put pressure on budgets and have a rather negative impact on health care and pension systems. In Germany, the expenditure on healthcare increased by an average of 2.6% per annum between the years 1995 and 2004 (Federal Statistical Office Germany, 2006). Therefore, this indicator is less meaningful in the case of Germany since growing pension and healthcare budgets must be seen—even from the perspective of disaster reduction and especially of sustainable development—as an aggravating factor rather than a capacity for higher resilience. Also some other indicators such as the number of 'hospital beds per 1000 people' imply a certain model of health infrastructure which might not be appropriate for poor rural areas, where the model of 'the doctor on a bicycle' is much more efficient and cost effective.

Nevertheless, the Americas Project and the associated type of assessment is very useful in directing attention to disaster risk and promoting an exchange of information, but the case is less clear in respect of meeting other expressed objectives of the indices. This is particularly the case when assisting policy makers to identify priorities for investment, since the specific indicators might be suitable for a specific country or region but not for another one. The approach offers new insights into how to measure and quantify vulnerability at the national scale for Latin America and the Caribbean, but for other countries—particularly highly developed countries, such as Chile or countries in Central Europe—the indicator and index set have to be reviewed.

Also, the evaluation of 'risk-management performance' provides an excellent overview of potential indicators and criteria which might be used to evaluate activities undertaken to reduce disaster risk. On the other hand, these actions also need to be suitable for the specific regional and local context, thus calling for specific adjustments (i.e. a specific contextualisation and adaptation) to indicators playing a crucial role. For example, the indicator of 'relocation of persons living in disaster-prone areas and improvements to housing in those areas' might be an appropriate indicator for certain countries where relocation is politically and culturally accepted; however, for other countries relocation and forced migration are part of the problem and imply new vulnerabilities. Therefore, risk-management strategies need to take into account the specific context (contextualisation) of the country and the broader livelihood framework in which vulnerable people are embedded. Additionally, it is important to examine whether the different indicators are sensitive enough to provide a tool to measure risk-management performance. Many political decisions do not lead to immediately visible changes: these often become visible only in the medium and long term. This is true, for example, of the improvement of urban and settlement structures.

Overall, the approach offers new insights into how to measure vulnerability as an intrinsic feature, as well as data already available mainly at the international and national levels. The underlying methodology of the RMI can also serve as an interesting example of how to provide quantitative measures of management-based on pre-defined qualitative subjects and the respective targets and benchmarks.

4. Local risk and vulnerability assessment

At the local level, a wide variety of approaches have been applied to measure and assess vulnerability and risk to hazards of natural origin. A comprehensive compilation of various approaches to measuring vulnerability and risk at different levels can be found in Birkmann (2006). In this paper, we introduce the Community-Based Risk Index developed by GTZ and partners for communities in Indonesia, since it also focuses on quantifying risk by using selected indicators, viewing risk as a sort of combination of hazard, exposure and vulnerability (see in detail Bollin and Hidajat, 2006).

4.1. The Community-Based Risk Index

The Community-Based Risk Index aims at identifying and quantifying the main risk characteristics (exposure, vulnerability, management capacities) within a community. It has the function of comparing risk between different communities, as well as the goal of identifying whether the level of risk is primarily an outcome of the hazard, the exposure, the vulnerability or the capacity component (see Bollin and Hidajat, 2006). As its conceptual framework, this approach relies on disaster-risk definitions put forward by Davidson (1997) and Bollin et al. (2003), which characterise disaster risk in terms of four components: hazard, exposure, vulnerability and capacity measures. The total indicator system comprised 47 indicators, arranged and systematised into four main factors and further calculated into factor components. The indicators selected to measure vulnerability focus on four different thematic areas: physical/demographic, social, environmental and economic vulnerability. The physical/demographic vulnerability includes indicators such as 'population density' and 'demographic pressure', while social vulnerability is quantified by assessing 'poverty levels', 'literacy rate' and 'decentralisation', among other indicators (see in detail Bollin and Hidajat, 2006). For each indicator, classifications were developed for low, medium and high risk. Moreover, the different indicators were weighted according to their importance for the specific hazard; here the

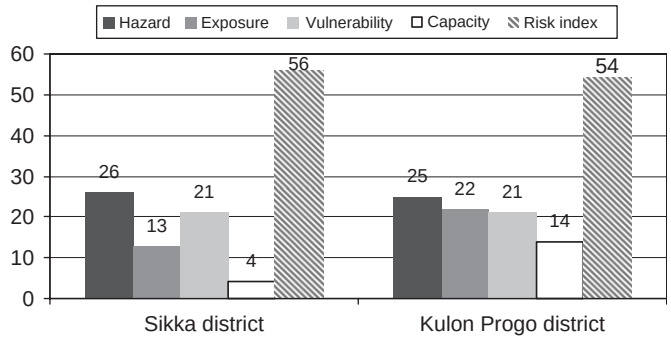

Fig. 5. Comparison of a community in Sikka district and a community in Kulon Progo district. *Source*: Bollin and Hidajat (2006).

weighting factors aimed at providing a tool to adjust the different measures to the country-specific conditions.

All indicators for the four sub-categories (hazard, exposure, vulnerability and capacity) were integrated into one index, i.e. the exposure index. Depending on the scaled indicator values, the factor indices vary between 0 and 100. This was achieved by distributing a total of 33 weighting points according to the assumed importance of the indicators for each factor (Bollin and Hidajat, 2006). The community-based Risk Index allows for the comparison of different communities across a country. Furthermore, it highlights the determining factors of risk, for example whether risk originates primarily from the hazard or whether the vulnerability or the lack of capacity is the major concern. Fig. 5 shows the results of the Community-Based Disaster-Risk Index for two communities in Indonesia.

The figure shows that for the community in the Sikka district hazard and vulnerability are major factors contributing to overall risk, while for the community in the Kulon Progo district there is a more equal distribution of risk-generating factors between hazard, exposure, vulnerability and capacity.

4.1.1. Discussion: applicability and usefulness

The Community-Based DRI provides comparative information on many aspects of development, vulnerability and disaster risk. However, this approach also raises difficult questions regarding the choice and aggregation of the indicators. Some indicators selected and aggregated are to a certain extent redundant. Moreover, some indicators are very context-specific and need to be handled with care when using them for other communities. This is true, for instance, of such indicators as 'accessibility', calculated by the number of interrupted roads due to natural hazards in the last 30 years. This indicator only provides adequate information regarding cities with a comparable size and structure. In other words, the total number of interrupted roads does not provide meaningful insights when comparing cities of different size since larger cities by 'nature' have more access roads and, therefore, alternative connections. In contrast, the interruption of one or two roads in a small city and village often has major implications for the mobility of people. This means that modifications are needed within the indicator approach in order to ensure that the approach takes account of the context, such as the differences between urban and rural communities. Overall, the approach provides an interesting compilation of indicators for physical, social, economic and also environmental vulnerability on the local level.

5. Reflection

The analysis and discussion of the approaches and indicators for risk and vulnerability at different levels showed that these approaches can serve as important tools—among others (e.g. qualitative assessment approaches)—for identifying and highlighting areas most at risk and where risk and vulnerability reduction is needed. However, major shortcomings were also revealed. In the following, discussion will focus on the challenges and limitations regarding the data, the issues of up- and downscaling, contextualisation and the policy relevance of the approaches. These aspects are part of the on-going discussion and are relevant for many other approaches aiming at measuring and quantifying risk and vulnerability at a global, national, sub-national and local level.

5.1. Data

The vulnerability and risk indicators discussed above have been calculated mainly with publicly available data, and in the case of the Community-Based Risk Index by means of interviews. In other words, the indicators and data used within these approaches are generally assessable or quantifiable. Yet some of the approaches presented—such as the DRI—are confronted with a lack of appropriate data for some areas, which limits indicator development and narrows the focus of the approach. To a large extent, the indicators are data-driven in the sense that the data determine the choice of indicator. Although mortality and economic losses are often the most accepted indicators in various countries to represent potential risks and vulnerabilities, the approaches are confronted with major limitations regarding the existing data. The DRI and Hotspots are based mainly on EM-DAT data generated by the CRED. These data focus solely on large- and medium-scale disasters, defined as those events involving more than 10 deaths, with 100 people affected and/or a call for international assistance. This means the impacts or potential impacts of creeping processes such as drought or sea-level rise (using historical data) will be only partially captured within this data set. Moreover, the timeframe used within the different approaches needs to be studied carefully if the aim is to derive conclusions for policy recommendations for the future. The Global Index Projects, especially the DRI and Hotspots, often focus on historical losses (loss of life and economic losses) over the last 20–25 years. This timespan is relatively short for low-frequency hazards such as earthquakes or tsunamis.

This problem becomes evident in the case of the relative-vulnerability measurement, which indicates that Venezuela is highly vulnerable to floods. Whether Venezuela is most vulnerable at present or in the future is a different subject.

Because of the paucity of historical data and due to the choice of indicators by some approaches, e.g. mortality as a main characteristic of vulnerability, it is difficult to estimate economic and human risks for slow-onset hazards, such as sea-level rise or drought. Impacts of sudden-onset hazards and slow-onset hazards particularly manifest themselves in much more diverse ways and with different characteristics, than mortality (see also Pelling, 2004, 2006). For example, in the case of slow-onset hazards the fatalities observed during drought periods in some regions may not primarily be the result of the drought, but may rather be the result of other influences, such as violent conflicts, or even of both: drought and civil war, as seen, for example, in Sudan and at the Horn of Africa (see Dilley et al., 2005, p. 65; World Disasters Report 2005, p. 214; UNICEF, 2006; BBC, 2000).

5.2. *Up- and downscaling and contextualisation*

Since major decisions in risk reduction and vulnerability have to be made and implemented at national and/or local level, the international discussion of global assessment approaches gives emphasis to the question of how to downscale global risk and vulnerability indicators and indices. For example, the shift from global assessment towards the design of national- and sub-national-scale risk assessments is and will be an important issue within the Global Risk Identification Program (GRIP) (see e.g. GRIP webpage). A major motivation for downscaling global approaches is the goal of supporting high-risk countries with capacities and information to identify and map risk hotspots at national and sub-national level in order to support priority setting for risk-reduction strategies and to demonstrate that evidence on risks and losses can improve risk management (see e.g. Lerner-Lam, 2006). The discussion has just started as to whether and how global approaches and the associated indicators can be downscaled and whether they provide appropriate and useful information.

The general methodology of measuring 'relative vulnerability' within the DRI, as well as the identification of 'Hotspots' for estimating and comparing the mortality-related risk and vulnerability of countries to different hazards at the global level using national-scale resolution, can also be downscaled. However, the usefulness of the global indicators and assessment methodology at a lower level will depend on the specific function (e.g. comparison or evaluation of policy interventions, etc.) which the approach is intended to fulfil. For example, the DRI calculation might be primarily useful at the national level for large countries that have faced major fatalities due to hazards of natural origin in the last few years, such as China or India. By contrast, for countries like Germany, for example, the mortality-related risk is not an appropriate measure, particularly at sub-national level, since risk and vulnerability manifest themselves in other characteristics. The Hotspots approach already provides information at a fine resolution. The results of the downscaling of the approach for Sri Lanka for the risk to drought, floods, landslides and cyclones show that the analysis can also be carried out at sub-national resolution. However, the outcomes are questionable, or at least difficult to interpret (see Dilley et al., 2005, p. 104). This means that modifications to the Hotspots methodology and indicators are also needed when targeting sub-national-level risk identification.

The Americas Project includes a large number of indicators—24 solely for the PVI; this means the focus is broader and more comprehensive than that of the DRI and Hotspots Project. Although this approach is applied in 12 countries in Latin America, and also additionally with some modifications at the sub-national scale for Colombia and for the city of Bogota (see Cardona, 2005, p. 23, 27), the downscaling of the approach to sub-national and local level requires a critical review of the indicators and weighting used. For example, three indicators within the PVI capture poverty. These indicators should be reviewed (redundancy) and adjusted to the specific context at sub-national and local level. For developed countries, the unemployment rate is often a more comprehensive indicator to measure socioeconomic exclusion and poverty than the general 'Human Poverty Index'.

Similar problems arise regarding other indicators such as the 'population density', which can have a widely different indicative power in terms of different regions and hazards. For example, population density might be an appropriate measure to indicate vulnerability regarding earthquakes; however, Cross (2001) argues that small cities and rural communities—which by definition have a lower population density—are more vulnerable to disasters, since large cities and megacities often have considerable resources for dealing with hazards and disasters.

Therefore, an important future challenge is to examine in greater depth how to "contextualise" the indicators and assessment approaches for the sub-national and local levels. 'Contextualisation' means to adjust indicator and index approaches to the specific socioeconomic context they are applied to and to the function (e.g. spatial comparison, guiding risk-management actions, evaluation of policy interventions) they are intended to serve.

Also within the upscaling of local approaches such as the Community-Based Disaster-Risk Index developed by GTZ, a critical review of indicators and their meaning is needed. Theoretically, the Community-Based Disaster-Risk Index can be applied at different scales, especially since most indicators—for example, 'poverty level', 'literacy rate' and 'diversification of the economy'—focus on general features that can be examined at the sub-national or national scale (see in detail Bollin and Hidajat, 2006). On the other hand, some indicators are useful

primarily at the local scale, such as indicators used to measure 'decentralisation' and the 'local resource base' (see in detail Bollin and Hidajat, 2006).

It is interesting to note that the discourse regarding 'contextualisation of indicators' is discussed more intensively within the framework of sustainable development. In this context, the discussion focuses particularly on how to contextualise sustainable development within different regional and local contexts (see e.g. Rink et al., 2005). Transferred to the discussion on measuring risk and vulnerability, 'contextualisation' implies two major questions:

1. how to operationalise and translate the concept of risk and vulnerability into quantitative and qualitative measures, and
2. how to design and adjust the measurement tools for specific functions (e.g. risk identification or evaluation of risk-management performance) and for specific target groups (e.g. disaster managers or urban planners).

6. Policy implications

Although the policy relevance of indicators and assessment tools of risk and vulnerability is a crucial issue, it is very difficult to define whether these approaches have already achieved high policy relevance or not. Some of the impacts might only become visible after some years. Nevertheless, some interesting observations can be made based on the findings of the first phase.

Firstly, although it remains an open question whether and to what extent the World Bank might use the Hotspots project, the high level of attention it attracts in the media—for example, particularly at MSNBC (US national broadcasting)—is a good indication of the policy interest it arouses (see e.g. MSNBC website). Furthermore, the World Bank is going to support a new phase of a GRIP, which also shows that it views the indicator-based assessment of risk as an important issue for its own policy.

Secondly, it is interesting to note that the development of the DRI of UNDP also had an impact on the development of a similar risk index and indicator assessment within the Humanitarian Aid Office of the European Commission (ECHO). Especially within the framework of the disaster-prevention and preparedness policy, known by the acronym DIPECHO, the UNDP's DRI was used as one element for identifying high-risk countries and those countries where aid and intervention are most needed (see ECHO, 2004, p. 4). This shows that risk and vulnerability indicators, and the approaches presented, can have an important policy impact when aid and development agencies like ECHO and the World Bank use these or similar methodologies to define priority countries for aid, disaster prevention and vulnerability reduction. However, within ECHO the quantitative indicator-based needs-assessment approach has also continuously been a subject of controversy—especially with some regional units. Currently, it is not clear to what extent these quantitative measures are being used to guide policies in ECHO, especially regarding the selection of priority countries.

Thirdly, within the framework of the Americas Project, a more in-depth dialogue has been started on how to apply the indicators. In addition to the pertinent discussions conducted in various workshops held with experts and government officials of the countries analysed, such as Colombia, Argentina, Guatemala, Bolivia, the Inter American Development Bank (IDB) has formally provided the country profiles on risk assessment—comparing the risk development of each respective country from 1980 to 2000—to authorities in each country (Cardona, 2006b). Moreover, the IDB has used the results and methods of the Americas Project to formulate the new Plan for Action on Disaster Prevention issued for the period 2005–2008. Thus, a dualistic application process has become visible, focusing on policy makers in the countries as a crucial target group, on the one hand, and on IDB using the indicators for its own policy development, on the other. Additionally, the World Bank has started to discuss the use of the Americas Project indices for defining development-assistance priorities to some countries in Latin America. Finally, the local application of the RMI in Bogotá has received positive feedback and the results are used for the formulation and updating of the city's risk-management plan (Cardona, 2006b). Thus the visible results of the application of the Americas Project are quite advanced, although the project only recently finished its first phase. A second phase is foreseen which will address particularly—under the heading of 'dialogues with the countries'—the application and implementation of the indicators at a national scale (Cardona, 2006b).

Overall, the examples show that Risk- and Vulnerability-Index and indicator approaches can be used, and are often indirectly used, as one tool to identify priority areas and targets where policy intervention is most needed.

Indicators and indices which use just some figures to represent complex phenomena and problems do offer certain advantages for policy making (easy communication of problems). On the other hand, national ministries as well as funding and aid agencies tend to avoid the use of these indicators for evaluating and publicising their effectiveness. This means indicators and the global identification of high-risk countries can contribute to prioritising and formulating policies, but the interest of politicians in using indicators as a transparent evaluation tool is limited. Additionally, policy makers as well as aid agencies, such as the Red Cross, are often interested in demonstrating and quantifying the positive effects of the interventions undertaken. Although economic losses and mortality are crucial aspects of risk and vulnerability, it will be difficult to use these indicators to evaluate the effectiveness of policy intervention in the short and medium term. The DRI and the Hotspots approach focus primarily on revealed vulnerability (historical mortality and economic losses),

while the Americas Project and the community-Based Disaster-Risk Index encompass a variety of indicators and indices which relate to a specific understanding of risk, vulnerability, preparedness and mitigation. In this context, the indicators can offer a systematic approach to discuss and evaluate different features of risk and to strengthen capacities to reduce disaster risk and vulnerability before a real disaster occurs. Additionally, indicators should also be used as a basis for discussion to choose targets for vulnerability and risk reduction. One of the major problems in the future development of indicators and tools to measure vulnerability and risk is the absence of clear goals of risk and vulnerability reduction. Consequently, the approaches focus primarily on the differences between countries (relative risk and vulnerability), not knowing precisely whether the overall risk or vulnerability is high or low. The classification of indicator values in terms of high, middle and low is therefore determined by the differences between various countries and groups, rather than by a precise definition of a risk and vulnerability baseline or respective risk- and vulnerability-reduction goals.

Lastly, risk and vulnerability indicators can provide a tool to examine and discuss the root causes of risk and vulnerability. However, this discussion needs to be facilitated by additional frameworks and approaches, such as for example the 'Sustainable Livelihood Approach' (DFID, 1999), the framework of the 'double structure of vulnerability (Bohle, 2001) or the 'Pressure and Release Model developed by Wisner et al. (see in detail Wisner et al., 2004, p. 51) and/or the BBC-framework (see Birkmann, 2006).

7. Conclusions

One of the most important goals of developing tools for measuring vulnerability is to help bridge the gaps between the theoretical concepts of vulnerability and day-to-day decision making. Therefore, it is important to view vulnerability as a process. Within this process, measures and instruments need to be defined which allow us to assess the past, current, and potential future areas and people at risk or vulnerable. Besides the generation of new and better data for global and local vulnerability and risk assessment, it is also important to strengthen co-operation and exchange between global and local approaches. Often these approaches tend to stay in separate corners. The concepts presented primarily focus on approaches applied within the disaster-risk community; a more intensive exchange of approaches to measure and assess vulnerability between the social-vulnerability school (see e.g. Bohle, 2001; Downing, 2004, DFID, 1999) and the global environmental change community (e.g. Turner et al., 2003) is desirable. For example, within the framework of the proposed GRIP Initiative and also the International Expert Working Group on Measuring Vulnerability established by UNU-EHS, exchange and co-operation between the different schools could be strengthened.

Furthermore, the analysis of the Hotspots and DRI concept shows that these approaches cover only the first and second spheres of the concept of vulnerability (see Fig. 1). The Americas Project encompasses a more comprehensive indicator set, including the aspect of the lack of coping capacity and resilience, and also the Community Disaster-Risk Index, incorporates both capacity and measures as response categories. On the other hand, environmental and institutional aspects, as well as the topic of adaptation (medium- and long-term adaptation) are only partially operationalised and covered within the approaches presented. Therefore, more research is needed to explore how to capture institutional and environmental vulnerabilities as well as learning processes (e.g. regarding adaptation vs. coping) and how to increase the capacities for medium- and long-term resilience to creeping and sudden-onset hazards of natural origin.

It is evident that more transparency and more information about the most vulnerable areas and groups are needed in order to make more appropriate information available to national and local decision makers for risk and vulnerability reduction, and also to provide the growing global disaster-response community with more precise knowledge on who to target first in or before a disaster situation. This means we need more research on how to measure vulnerability and risk as well as on how to improve and adjust existing indicator approaches for specific purposes and different scales. The four approaches reviewed in this paper are an important basis for this further improvement of monitoring tools. Additionally, qualitative data and information have to be integrated in order to achieve a more comprehensive picture about risk and vulnerability, particularly with regard to the root causes and the driving forces of vulnerability.

References

Bankoff, G., Frerks, G., Hilhorst, D. (Eds.), 2004. Mapping Vulnerability, Disasters, Development and People. Earthscan Publishers, London.

Birkmann, J., 2005. Danger need not spell disaster—but how vulnerable are we? Research Brief, Number I, United Nations University, Tokyo.

Birkmann, J. (Ed.), 2006. Measuring Vulnerability to Natural Hazards—Towards Disaster-Resilient Societies. UNU Press, Tokyo, New York.

Birkmann, J., Wisner, B., 2006. Measuring the un-measurable. The challenge of vulnerability. Source, No. 5/2006. United Nations University—Institute for Environment and Human Security, Bonn. Available at: 〈http://www.ehs.unu.edu/file.php?id=212〉.

Bogardi, J., Birkmann, J., 2004. Vulnerability assessment: the first step towards sustainable risk reduction. In: Malzahn, D., Plapp, T. (Eds.), Disaster and Society—From Hazard Assessment to Risk Reduction. Logos Verlag, Berlin, pp. 75–82.

Bohle, H.-G., 2001. Vulnerability and criticality: perspectives from social geography. IHDP Update 2/2001, Newsletter of the International Human Dimensions Programme on Global Environmental Change, pp. 1–7.

Bollin, C., Cárdenas, C., Hahn, H., Vatsa, K.S., 2003. Natural Disasters Network: Comprehensive Risk Management by Communities and Local Governments. Inter-American Development Bank. Available at 〈http://www.gtz.de/en/themen/uebergreifende-themen/nothilfe/1817.htm/〉.

Bollin, C., Hidajat, R., 2006. Community-based disaster risk index: pilot implementation in Indonesia. In: Birkmann, J. (Ed.), Measuring Vulnerability to Natural Hazards—Towards Disaster Resilient Societies. UNU-Press, Tokyo, New York, Paris.

British Broadcasting Corporation, 2000. War and drought in the horn. Available at: 〈http://news.bbc.co.uk/1/hi/world/africa/762235.stm〉.

Cardona, O.D., 2004. The need for rethinking the concepts of vulnerability and risk from a holistic perspective: a necessary review and criticism for effective risk management. In: Bankoff, G., Frerks, G., Hilhorst, D. (Eds.), Mapping Vulnerability: Disasters, Development and People. Earthscan Publishers, London.

Cardona, O.D., 2005. Indicators of disaster risk and risk management—main technical report. IDB/IDEA Program of Indicators for Disaster Risk Management, National University of Colombia, Manizales. Available at 〈http://idea.unalmzl.edu.co〉.

Cardona, O.D., 2006a. A system of indicators for disaster risk management in the Americas. In: Birkmann, J. (Ed.), Measuring Vulnerability to Natural Hazards—Towards Disaster Resilient Societies. UNU-Press, Tokyo, New York, Paris.

Cardona, O.D., 2006b. Personal notes on the application of the indicators and indexes of the Americas Project at national and local level (communication via e-mail dated 5 June 2006).

Cardona, O.D., et al., 2004. Results of application of the system of indicators on twelve countries of the Americas. IDB/IDEA Program of Indicators for Disaster Risk Management, National University of Colombia, Manizales. Available at 〈http://idea.unalmzl.edu.co〉.

Chen, R., 2006. Current hotspots limitations & potential improvements or how to clean up the hot spots in hotspots! Presentation at Proposal Development Coordination Meeting, 19 May 2006, Columbia University, New York. Available at 〈http://www.ldeo.columbiachrr/news/2006/documents/GRIP_19May06_LimitationsImprovements_Chen.pdf〉.

Cross, J.A., 2001. Megacities and small towns: different perspectives on hazard vulnerability. Environmental Hazards 3 (2), 63–80.

Davidson, R., 1997. An urban earthquake disaster risk index. Report No. 121, The John A. Blume Earthquake Engineering Center, Stanford.

Department for International Development (DFID), 1999. Sustainable Livelihood Guidance Sheets. DFID, London. Available at: 〈http://www.livelihoods.org/info/info_guidancesheets.html〉.

Dilley, M., 2005. Setting priorities: global patterns of disaster risk. Paper of the Scientific Discussion on Extreme Natural Hazards, Royal Society, 26–27 October 2005, London (unpublished).

Dilley, M., Chen, R.S., Deichmann, U., Lerner-Lam, A., Arnold, M., 2005. Natural Disaster Hotspots. A Global Risk Analysis. The World Bank, Hazard Management Unit, Washington, DC.

Downing, T., 2004. What have we learned regarding a vulnerability science? In: Science in Support of Adaptation to Climate Change. Recommendations for an Adaptation Science Agenda and a Collection of Papers Presented at a Side Event of the 10th Session of the Conference of the Parties to the United Nations Framework Convention on Climate Change, Buenos Aires, 7 December 2004, pp. 18–21. Available at 〈www.aiaccproject.org/whats_new/Science_and_Adaptation.pdf〉.

European Commission Humanitarian Aid Office (ECHO), 2004. ECHO Decisions—Manual of Procedures, vol. II, Disaster Preparedness, Brussels.

Federal Statistical Office Germany, 2006. Gesundheit. Ausgaben, Krankheitskosten und Personal 2004. Available at: 〈http://www.destatis.de/presse/deutsch/pk/2006/gesundheit_2004i.pdf〉.

Global Risk Identification Programme (GRIP). Website 2006, Available at 〈http://www.ldeo.columbia.edu/chrr/news/2006/grip.html〉.

Lerner-Lam, A., 2006. Workshop Summary—Global Risk Identification Program (GRIP). Risk Sub-programme Planning Workshop 4–6 January 2006. Colombia University, New York. Available at: 〈www.Ideo.columbia.edu/chrr/news/2006/grip.html〉.

MSNBC website (access 25-05-2006). Scientists chart global disaster hot spots—maps provide guide for preparedness and investment. Available at 〈http://www.msnbc.msn.com/id/6799055/〉.

Peduzzi, P., 2006. The disaster risk index: overview of a quantitative approach. In: Birkmann, J. (Ed.), Measuring Vulnerability to Natural Hazards—Towards Disaster Resilient Societies. UNU-Press, Tokyo, New York, Paris.

Peduzzi, P., Dao, H., Herold, C., 2005. Mapping disastrous natural hazards using global datasets. Natural Hazards 35 (2), 265–289.

Pelling, M., 2004. Visions of Risk: A Review of International Indicators of Disaster Risk and its Management. UNDP—Bureau for Crisis Prevention and Recovery (BRCP), Geneva.

Pelling, M., 2006. Review of global risk index projects: conclusions for sub-national and local approaches. In: Birkmann, J. (Ed.), Measuring Vulnerability to Natural Hazards—Towards Disaster Resilient Societies. UNU Press, Tokyo, New York, Paris.

Rink, D., Hartmuth, G., Huber, K. (Eds.), 2005. Raum für Nachhaltigkeit—Zur Kontextualisierung des Leitbilds. Edition Sigma, Berlin.

Special Coordinator of the Stability Pact for South Eastern Europe (SCSP), 2006. Report on April 2006 floods in South Eastern Europe. Available at: 〈http://www.reliefweb.int/rw/RWB.NSF/db900SID/VBOL-6Q4GZJ?OpenDocument&rc=4&cc=rou〉.

Thywissen, K., 2006. Core terminology of disaster reduction: a comparative glossary. In: Birkmann, J. (Ed.), Measuring Vulnerability to Natural Hazards—Towards Disaster Resilient Societies. UNU-Press, Tokyo, New York, Paris.

Turner, B.L., Kasperson, R.E., Matson, P.A., et al., 2003. A framework for vulnerability analysis in sustainability science. Proceedings of the National Academy of Sciences 100 (14), 8074–8079.

United Nations Children's Fund (UNICEF), 2006. Sudan. Dafur—Overview. Available at: 〈http://www.unicef.org/infobycountry/sudan_darfuroverview.html〉.

United Nations Development Programme (UNDP), 2004. Reducing disaster risk. A challenge for development. A Global Report, UNDP—Bureau for Crisis Prevention and Recovery (BRCP), New York. Available at 〈http://www.undp.org/bcpr/disred/rdr.htm〉.

United Nations International Strategy for Disaster Reduction (UN/ISDR), 2004. Living with Risk. A Global Review of Disaster Reduction Initiatives. 2004 version. UN Publications, Geneva.

Wisner, B., 2002. Who? What? Where? When? in an emergency: notes on possible indicators of vulnerability and resilience: by phase of the disaster management cycle and social actor. In: Plate, E. (Ed.), Environment and Human Security: Contributions to a Workshop in Bonn, 23–25 October 2002, Germany, pp. 12/7–12/14.

Wisner, B., Blaikie, P., Cannon, T., Davis, I., 2004. At Risk: Natural hazards, People's Vulnerability and Disasters, second ed. Routledge, London.