Assessing Human Vulnerability to Environmental Change

Concepts, Issues, Methods and Case Studies

DISCLAIMER

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Foreword

Most of the world is undergoing fundamental demographic, political, socio-economic and environmental change. The human population is projected to increase from 6 billion in 1999 to 7.3 to 10.7 billion in 2050. The twenty-first century will witness unprecedented expansion in almost every domain of human activity, and greater pressure on resources. Human society will become increasingly vulnerable to environmental change. Natural disasters, technological accidents, biological outbreaks and degradation of life-support systems can result in immense human suffering, and in loss of life, property and infrastructure. The consequences of such events are increasing dramatically.

Assessments of vulnerability, carried out holistically, can provide an important guide to the planning process and to decisions on resource allocation at various levels, and can help to raise public awareness of risks. Such assessments can help to provide answers to basic questions such as who is vulnerable, where and why - answers which are essential when developing early-warning systems to improve preparedness.

This ongoing process, which reviews various concepts of vulnerability, methodologies for vulnerability assessment, and vulnerability indices, operates within the framework of the United Nations Environment Programme's (UNEP) Global Environment Outlook (GEO).

A new framework for assessing human vulnerability to increasing environmental change has been proposed, which should lead to stronger societal commitment to the environment. Eight different channels through which human welfare will be affected by environmental degradation are: *Damage to Health, Economic Loss, Poverty, Food Insecurity, Loss of Intellectual Property Rights (IPR), Loss of Natural Heritage, Conflict, and Vulnerability Impacts of Extreme Events/Natural Hazards and Climate Change.*

This study concludes that vulnerability is a function not only of exposure to hazards, but also of population density and coping capacity over time. Consequently, poor people in developing countries are more vulnerable than their richer counterparts. Hence the best defence against vulnerability is raising the financial and social capital of the world's poor.

Assessing vulnerability to multiple sources of stress such as environmental changes is a demanding task. I hope that the international scientific community will accept this challenging assignment and develop future research agendas around these themes.

The basic goals of such research would be to provide a framework for assessing the increasing human vulnerability to environmental changes in a holistic manner and to explore and share the subject matter further with academics, policy makers and practitioners around the world. The most important thing is to participate in this adventure and work together to enable multiple dimensions to converge into one and discover, in the phrase of the eminent biologist E.O. Wilson, "the possible consilience".
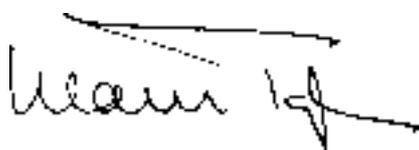
Klaus Toepfer
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Executive Summary

In the last century the Earth's population grew from 1.6 to about 6 billion people. There has been enormous expansion in economic activity, infrastructure development, human settlements, industrial growth, technological deployment and interdependence. This unprecedented growth has significantly increased societal vulnerability to the vagaries of climate change, land-use impacts, natural hazards and other environmental events. Vulnerability assessment is needed to identify hazardous geographic regions and specific populations at risk, to enable them to be provided with timely help. It is vital to rank hazards according to their probability of occurrence and the seriousness of their consequences, and to conduct cost-benefit analyses of preparedness programmes. Priorities must be set to ensure that any mitigation measures adopted protect the maximum number of people in a cost-effective manner.

This study reviews various concepts of vulnerability, methodologies for vulnerability assessment, and recent work on vulnerability assessment and indices. An attempt has been made to assess the vulnerability due to a single hazard component such as cyclones in the South Asia, using Geographic Information System (GIS) tools. It has also made progress towards a general conceptual framework for assessing increasing human vulnerability to multiple hazards such as environmental changes, and a composite vulnerability index.

The study has revealed that there are various concepts of vulnerability such as social, economic, environmental, food security, natural hazards and climatic change impacts. There are three broad approaches to vulnerability assessment: analysis of statistical data, spatial analysis, and modelling. Vulnerability is defined here as a function of exposure to hazard, population density and the coping capacity of people over time.

The main findings are:
- In 1999, the death toll from infectious diseases (such as HIV/AIDS, malaria, respiratory diseases and diarrhoea) was 160 times that caused by natural disasters, including the massive earthquakes in Turkey, floods in Venezuela and cyclones in India. The situation is getting worse. HIV/AIDS is expected to kill more people in sub-Saharan Africa alone during the next ten years than the number killed in all the wars of the 20th century.

- Countries with high per-capita income have lower rates of fatality due to disasters because of their better coping capacity, while poorer countries have higher rates because of inferior coping capacity. For example, the number of reported disaster events in the United States between 1990 an 1999 were more than twice that in India and about three times that in Bangladesh. However, the number of deaths in India was 14 times and in Bangladesh 34 times than in the United States. Exposure to extreme events is thus not necessarily the main determinant of vulnerability.

- Access to safe drinking water in Bangladesh has declined by 17 per cent in the last three years due to arsenic contamination in groundwater. An estimated 75 million people are vulnerable to arsenic poisoning, leading to a serious health crisis.

- A GIS-based case study showed that more than five hundred million people, in different states in India, are vulnerable to cyclones. The people of Orissa, one of the poorest states in India, are extremely vulnerable because of its location in the cyclonic zone and their extreme poverty.

Part 1: Introduction

1.1   Background

In the last century, the Earth's population grew from 1.6 to about 6 billion people. There has been enormous expansion in economic activity, infrastructure development, human settlements, industrial growth, technological deployment and interdependence. This unprecedented growth has significantly increased societal vulnerability to a host of human-induced and natural hazards. The developing world is more vulnerable because of the increasing exposure of more and more people to various hazards and their limited coping capacity. To understand the vulnerability of people, one would have to integrate data from multiple sources in a particular context, which could then guide targeted efforts to mitigate the situation. In order to take practical steps to reduce human vulnerability to numerous hazards, it is essential to identify vulnerable regions and populations and escalating factors, and to ensure the timely communication of relevant information for decision-making.

This study reviews various concepts of vulnerability, methodologies for vulnerability assessment, and recent work on vulnerability assessment and indices. An attempt has been made to assess the vulnerability due to a single hazard component such as cyclones in the South Asia, using Geographic Information System (GIS) tools. It has also made progress towards developing a general conceptual framework for assessing increasing human vulnerability to multiple hazards such as environmental changes, and a composite vulnerability index.

1.2   Objectives of the study

The main objectives of the study were to:
- review the various concepts and issues of vulnerability;

- review the methodologies for vulnerability assessment and vulnerability indices;

- develop a general framework and attempt to construct a composite index to provide a measure of increasing environmental vulnerability due to multiple hazards such as environmental changes;

- provide some examples of vulnerability assessment methods using human health and arsenic contamination issues in Bangladesh and cyclonic impact in India.

1.3 Vulnerability: Concept and definitions

Vulnerability is a multidimensional concept. Although vulnerability is an intuitively simple notion, it is surprisingly difficult to define and even more difficult to quantify and apply in practice. It is described in the literature in many and sometimes inconsistent ways. Definitions of vulnerability range from a focus on physical exposure (Mitchell 1989; Schneider and Chen 1980; Barth and Titus 1984), through measures of socio-economic status and access to resources (Susman, O'Keefe, and Wisner 1983; Timmerman 1981; Cannon 1994) and sociological investigations of the differential ability of groups to resist harm and to recover afterwards (Drabek 1986; Bolin 1982; Quarentelli 1991), to discussions of how the 'hazard of place' is linked to social profiles (Dow 1992; Cutter 1996). Sample definitions of vulnerability, focusing on different issues, are summarised below:

Gabor (1979) referred to vulnerability as a threat to which a community is exposed, taking into account not only the properties of the chemical agents involved but also the ecological situation of the community and the general state of emergency preparedness, at any point in time.

Timmerman (1981) defined vulnerability as the degree to which a system reacts adversely to the occurrence of a hazardous event. The degree and quality of the adverse reaction are conditioned by the resilience of the system (a measure of its capacity to absorb and recover from the event).

Cutter (1993) defined vulnerability as the likelihood that an individual or group will be exposed to and adversely affected by a hazard. It is the interaction of the hazards of the place (risk and mitigation) with the social profile of the communities.

Anderson and Woodrow (1989) charted vulnerability and capability in relation to physical/material resources, social/organizational factors, and motivational/attitudinal aspects.

Blaikie et al. (1994) regarded vulnerability as a combination of such characteristics as ethnicity, religion, caste membership, gender and age that influence access to power and resources.

Bohle et al. (1994) defined vulnerability as an aggregate measure of human welfare that integrates environmental, social, economic and political exposure to a range of harmful perturbations. He suggests a tri-partite causal structure of vulnerability based on the human ecology of production, expanded entitlements in market exchanges, and the political economy of accumulation and class processes.

Moser (1996) defined vulnerability as the insecurity of the well-being of individuals, households, or communities in the face of a changing environment

Clark (1998) defined vulnerability as a function of two attributes: 1) exposure (the risk of experiencing a hazardous event); and 2) coping ability, subdivided into resistance (the ability to absorb impacts and continue functioning), and resilience (the ability to recover from losses after an impact).

Generally speaking, therefore, vulnerability is the manifestation of social, economic and political structures, and environmental setting. Vulnerability can be seen as made up of two elements: exposure to hazard and coping capability. People having more capability to cope with extreme events are naturally also less vulnerable to risk.

Vulnerability relates to the consequences of a perturbation, rather than its agent. Thus people are vulnerable to loss of life, livelihood, assets and income, rather than to specific agents of disaster, such as floods, windstorms or technological hazards. The locus of vulnerability is an individual related to the social structures of household, community, society and world-system. Places can only be ascribed a vulnerability ranking in the context of the people who occupy them. These concepts of vulnerability shift the focus of vulnerability away from a single hazard to the characteristics of the social system. Thus, vulnerability is explicitly a *social* phenomenon, a threat to a human system of social structure.

Different international organizations use different definitions of vulnerability, depending on their role or field of influence:

The World Food Programme (WFP) and the *Food and Agricultural Organization (FAO)* monitor vulnerability mostly to food crises. FAO defines vulnerability in relation to the full range of factors that place people at risk of becoming food-insecure. The degree of vulnerability of an individual, household or group of persons is determined by their exposure to the risk factors and their ability to cope with or withstand stressful situations. The Vulnerability Analysis and Mapping (VAM) project of WFP (1999), also defines vulnerability in terms of food security, as the probability of an acute decline in access to food or consumption levels below minimum survival needs. It is a result of exposure to risk factors, such as drought, conflict or extreme price fluctuations, and underlying socio-economic processes which reduce the capacity of people to cope. Thus, vulnerability can

be viewed as:

$$\text{Vulnerability} \cong \text{(proportionate to) exposure to risk + inability to cope}$$

The United States Agency International Development (USAID) (1999) referred to vulnerability as a relative measure in their Famine Early Warning System (FEWS). Their strategy on vulnerability was "everyone is vulnerable, although their vulnerability differs in its causal structure, its evolution, and the severity of the likely consequences".

The Commonwealth Secretariat (1997) argued that "vulnerability is the consequence of two sets of factors: (1) the incidence and intensity of risk and threat and (2) the ability to withstand risks and threats (resistance) and to 'bounce back' from their consequences (resilience)". Such threats were perceived to emanate from three main sources: economic exposure; remoteness and insularity; and proneness to natural disasters.

The United Nations (1982) distinguished two important considerations in the notion of vulnerability. First, they distinguished between economic vulnerability and ecological fragility, recognising that economic vulnerability finds its origins partly in ecological factors (for example, cyclones). Thus vulnerability indices "are meant to reflect relative economic and ecological susceptibility to exogenous shocks". Secondly, they made a distinction "between structural vulnerability, which results from factors that are durably independent from the political will of countries, and the vulnerability deriving from economic policy, which results from choices made in a recent past, and is therefore conjectural". UNDRO (1982) defined vulnerability as a degree of loss to the given elements of risk resulting from the occurrence of a natural phenomenon of a given magnitude.

The Intergovernmental Panel on Climate Change-IPCC (1997) defined vulnerability as the extent to which a natural or social system is susceptible to sustaining damage from climate change. Vulnerability is a function of the sensitivity of a system (the degree to which it will respond to a given change in climate, including both beneficial and harmful effects) and the ability of the system to adapt to changes in climate (the degree to which adjustments in practices, processes or structures can moderate or offset the potential for damage or take advantage of opportunities created, as a result of a given change in climate). Under this framework, a highly vulnerable system would be one that is highly sensitive to modest changes in climate, where the sensitivity includes the potential for substantial harmful effects, and one for which the ability to adapt is severely constrained.

The South Pacific Applied Geo-science Commission-SOPAC (1999) defined vulnerability as the potential for attributes of a system to respond adversely to the occurrence of hazardous events, and resilience as the potential for attributes of a system to minimise or absorb the impact of extreme events. Economic vulnerability is concerned with external forces, which act on the economy, while social vulnerability occurs when natural or other disasters force massive upheavals of residence, traditions and society. Environmental vulnerability differs from vulnerability of human systems because the environment is complex, with different levels of organization, from species to interdependent ecosystems, and the complex linkages between them.

In summary, human vulnerability can be defined as the exposure to hazard by external activity (e.g. the climatic change) together with the coping capacity of the people to reduce the risk from the exposure.

Vulnerability is also connected with access to opportunities, which defines the ability of people to deal with the impact of the hazard to which they are exposed. It means the characteristics of a

person or a group of people in terms of their capacity to anticipate, cope with, resist, and recover from the impact of the risk or hazard.

1.4   Vulnerability assessment and composite indices

Vulnerability assessment is significant for current and future planning exercises. It is way of establishing who is vulnerable, where they are and what are the strategies to combat vulnerability. It helps decision-makers in government, donor agencies and non-governmental organizations (NGOs) to work for vulnerable people. Proper risk management, preparedness, and critical decision-making (which requires the right information to the right people at the right time) are all essential if the most vulnerable people are to be given the assistance they need.

Composite indices have long been used in a wide variety of disciplines to measure complex, multi-dimensional concepts that cannot be observed or measured directly. Generally they combine several specific indicators. Their power lies in their ability to synthesise a vast amount of diverse information into a simple, usable form. The directness of the composite index makes the information easily accessible to the general public, UN development organizations, government agencies and other potential users.

1.5   Perception: Myths and realities

In a recent article in the Washington Post, David Ropeik (2000), Director of Risk Communication for the Harvard Center for Risk Analysis, dealt with the issues related to the perception of vulnerability. Public and private spending on the clean-up of hazardous waste in America is estimated at $30 billion a year. Ropeik argues that hazardous waste is a real problem, but the number of people whose health is at risk because of it is actually quite low. Compare that $30 billion with only $500 million a year spent on programmes to reduce smoking, one of the leading preventable causes of death in America. This raises the issues of perception, myths, and realities related to vulnerability. Ropiek explains that, in many areas, science can identify the physical hazards, the numbers likely to be affected by each one, and the various mitigation measures. But policies are normally based less on fact than on fear, which is more emotional than rational. Society, however, should be more rational because of limited resources and the need for responsible planning.

His article also highlights some universal perception factors, identified by social psychologist Paul Slovic and others. These make many people afraid of the same things; individual fears turn into group fears that then foster irrational government policy. Such factors include:

• CONTROL OR NO CONTROL: People normally feel in control when they drive, but not when they are an airplane passenger bumping through turbulence at 10 000 m (although the fatality rate per passenger km is far higher for cars than planes). When they are well-protected by a dam in a city, they feel in control and are not scared about floods.

• IMMEDIATE/CATASTROPHIC OR CHRONIC: People tend to be more afraid of events that can kill many people suddenly and violently, like a plane crash, than, say, lung cancer, which causes very much larger numbers of deaths, but slowly and over time. The deaths of hundreds of people following a sudden natural disasters attracts much media attention, while the larger number of deaths from chronic diseases like diarrhoea or malaria that can follow natural disasters, especially in developing countries, are seldom mentioned. Disease is a 'slow process disaster'.

- IMPOSED OR VOLUNTARY – Non-smokers are often fearful of tobacco smoke. Smokers usually are not. People living in developing countries get accustomed to floods and cyclones. They have less fear about their position than people from developed countries because they are more familiar with the incidents.

With a governmental process poisoned by selfish partisanship, often hostage to the influence of money and special interests, and spineless in the face of the latest media-fed fear frenzy, how can people get political leaders and government agencies to make wiser choices and protect people better? The author of the article recommends:

(1) listing the potential hazards, and ranking them on the basis of probability of occurrence;

(2) classifying risks according to the seriousness of the consequences; and

(3) conducting cost-benefit studies to help rank mitigation options, to identify those that will maximise resources to protect the most people.

Part 2: Review of recent work on vulnerability

2.1 Introduction

A number of studies related to vulnerability have been conducted by various organizations. These studies are summarised below. Most of the them focused on different issues: economic, environmental, and disaster vulnerability, and vulnerability due to food insecurity, etc. This review is an expanded version of an unpublished paper on vulnerability indices by the UN Department of Economic and Social Affairs, 2000.

2.2 Economic vulnerability

Economic vulnerability focuses on the potential negative effects of a range of factors, including economic structure and size, geographical handicaps and exposure to environmental risks, on economic growth and on the level of development.

2.2.1 The Committee for Development Policy (CDP)
The Committee for Development Policy has developed an economic vulnerability index (EVI) covering 128 developing countries for use in identifying the least developed among the developing countries. The CDP EVI identifies three aspects of vulnerability: size and structure of the economy, exposure to international trade shocks, and exposure to natural disasters (CDP 2000).

2.2.2 The Caribbean Development Bank (CDB)
The Caribbean Development Bank has developed another EVI covering 95 countries as a measure of the development challenge facing Caribbean developing countries. The CDB EVI identifies five factors which contribute to economic vulnerability: peripherality and energy dependence, export concentration, convergence of export destination, reliance upon external finance, and susceptibility to natural disasters (Crowards 1999).

2.2.3 Commonwealth Secretariat (CS)
The Commonwealth Secretariat has developed an economic vulnerability index designed to quantify vulnerability so that particularly vulnerable countries can be identified. Such an index can serve as an operational tool in determining whether small states should be accorded differential treatment by the international development community. Income volatility and

resilience are the two key dimensions of vulnerability. Income volatility is measured by a vulnerability impact score which is calculated by combining three variables: average exports of goods and non-factor services as a percentage of GDP, the UNCTAD index of merchandise export diversification, and the total number of people affected by natural disasters between 1970 and 1996 as a proportion of total population (Patkins et al 2000).

2.2.4 United Nations University (UNU)

The United Nations University Institute of Advanced Studies (UNU/IAS) has developed a geographic vulnerability index (GVI) covering 100 developing countries as a possible extension of other economic vulnerability approaches. It measures geographic vulnerability, with special reference to Small Island Developing States (SIDs). This GVI is a response to the call from the United Nations to develop a methodology for vulnerability assessment. It is a contribution to supplementing the existing criteria used for identification of least developed countries by the Committee for Development Policy. The UNU/IAS GVI identifies four dimensions of geographic vulnerability: insularity, peripherality, population concentration, and susceptibility to natural disasters (Turvey 2000).

2.2.5 United Nations Conference on Trade and Development

The Office of the Special Coordinator for Least Developed Countries and Land-locked and Island Developing Countries, in accordance with the recommendation by the Committee for Development Policy "that a document – to be called a country 'vulnerability profile' – should assess the impact of external economic and natural shocks on the economic performance and economic structure of a country", has produced vulnerability profiles for four least-developed island countries: Cape Verde, Maldives, Samoa and Vanuatu. The vulnerability profiles describe: (1) the nature of a range of external shocks, including environmental disaster, human disease epidemics, export volume and price fluctuations, and reductions in financial flows; (2) the implications for the economy of such shocks based on external economic dependence; and (3) island-specific handicaps and limitations to external shocks (CDP 1999).

2.3   Environmental vulnerability

Several organizations have developed indices to measure the vulnerability of people to environmental hazards:

2.3.1 The Commonwealth Secretariat

The Commonwealth Secretariat has developed an environmental index designed to be applicable to developing and island states and has compiled two variants for 111 countries. Six indicators were selected to reflect pressures on the natural environment: annual rate of deforestation (1980 - 1990), population density, annual water use as a percentage of total water resources (1980 - 1990), length of coastline compared to land area, number of threatened species compared to land area, and total number of natural disasters between 1970 and 1996 compared to land (Patkins 2000)

2.3.2 South Pacific Applied Geosciences Commission (SOPAC)

The focus of SOPAC is on the vulnerability of the environment to both human and natural hazards. The development of such an environmental vulnerability index would be an important step towards the development of a composite vulnerability index encompassing both economic and environmental vulnerability. SOPAC identifies three aspects of environmental vulnerability: level of risks (or pressures) on the environment; resilience of the environment to pressures, or intrinsic vulnerability;

and the level of degradation of ecosystems, or extrinsic resilience. A total of 47 indicators are used: 26 indicators of risk, 7 of resilience, and 14 of environmental degradation. The indicators are also classified by scientific category - meteorological, geological, biological, anthropogenic - and intrinsic country characteristics. The data were collected for five countries (Fiji, Samoa, Tuvalu, Vanuatu and Australia) for initial testing (SOPEC 2000).

2.3.3 Global Leaders for Tomorrow Environment Task Force, World Economic Forum

In collaboration with the Yale Center for Environmental Law and Policy (YCELP) of Yale University and the Center for International Earth Science Information Network (CIESIN) of Columbia University, a World Economic Forum task force has produced a Pilot Environmental Sustainability Index. This index was calculated for 56 economies, of which 25 are developing countries and 31 are developed countries or countries with economies in transition, utilising 64 individual variables covering five components regarded by the authors as fundamental for environmental sustainability:
   (1)   health of environmental systems;
   (2)   environmental stresses and risks;
   (3)   human vulnerability to environmental impacts;
   (4)   social and institutional capacity; and
   (5)   global stewardship (World Economic Forum 2000).

2.4 Vulnerability to natural disasters

Disaster vulnerability deals with the susceptibility of people to natural disasters like floods, droughts, cyclones and earthquakes. Many organizations have developed measures of disaster vulnerability through different techniques based on data from past events, including:

2.4.1 Annual review of Disasters - Munich Re Group

The annual review of disasters by a leading insurance company, Munich Re Group, discusses vulnerability related to natural disasters, based on studies of catastrophes all over the world. This analysis, through Natcat SERVICE information, shows that the highest frequency of disasters occurs in rich countries but that the impact of disasters was greatest on low per capita income groups in poor countries because of their low purchasing power (Munich Re Group 2000).

2.4.2 RADIUS Project - *An initiative for IDNDR, Office for the Coordination of Humanitarian Affairs, United Nations*

The Risk Assessment Tools for Diagnosis of Urban Areas against Seismic Disasters (RADIUS) project has developed a composite risk index to facilitate worldwide inter-city comparisons of the magnitude and nature of urban earthquake disaster risks. Earthquake Disaster Risk Index (EDRI) results are illustrated using a ten-city sample analysis, which allows direct comparison of the relative overall earthquake disaster risk and describes the relative contributions of various factors (e.g., hazard, exposure, vulnerability) to that risk. The index is calculated on the basis of 31 indicators covering five main factors: hazard, exposure, external context, vulnerability, and emergency response plan (Davidson 1998).

2.4.3 United Nations Development Programme (UNDP)

UNDP is developing a new report, which will implement a range of global policy initiatives focusing on key disaster reduction and recovery issues. They will launch a World Vulnerability Report (WVR) as a mechanism to focus the attention of governments and the international community on viable approaches to managing and reducing risk. The objectives of the WVR are: to monitor and promote, both as best practice and indicators for indexing, the efforts of countries in managing and reducing

disaster risks, to highlight comparative levels of and trends in disaster risk occurrence across countries, over time and between different risks and vulnerability types, and to identify the contribution of different factors to the configuration of disaster risk. (UNDP 2000, unpublished paper).

2.4.4 Vulnerability to Disaster and Epidemic - CRED and Red Cross

The Centre for Research on the Epidemiology of Disasters (CRED) and the Red Cross recently published its latest report on vulnerability to disasters. It found that, in 1999, the death toll from infectious diseases (such as AIDS/HIV, malaria, respiratory diseases and diarrhoea) was 160 times greater than the number killed in natural disasters including the massive earthquakes in Turkey, floods in Venezuela and cyclones in India (CRED 2000).

On some continents, more than half the total number of people reported killed during the past decade resulted from just one type of disaster. This is particularly true in Africa where more than 70 per cent of reported deaths were caused by epidemics. Waves/surges killed more than 60 per cent of the total number of people reported killed in Oceania: a tsunami killed about 2 200 people in Papua New Guinea in 1998. During the past decade in Europe, technological (non-natural) disasters killed almost the same number of people as natural disasters: 74 per cent of people killed by technological disasters died in transport accidents. Europe is the only continent where the consequences of technological disasters equal those of natural disasters. Finally, floods and windstorms caused 44 per cent of total deaths from natural disasters in Asia and 46 per cent in the Americas. Also notably, especially the 1999 Venezuelan floods, which claimed the lives of 30 000 people.

2.5 Vulnerability to technological disasters

People in the developed world show concern about radiation from power lines, cell phone towers and nuclear tests than natural disasters, although there is no firm evidence that such radiation has actually caused any deaths or injuries, at least among the general public directly. But, industrial disasters such as the Bhopal and Chernobyl tragedies in India and Ukraine have killed many people over the years. The 1984 Bhopal disaster killed 16 000 people and left about half a million people with permanent health injuries (Greenpeace International 1999). The Centre for Research on the Epidemiology of Disasters (CRED) collects data for technological as well as natural disasters as well. CRED has essential core data on the occurrence and effects of over 12 000 mass disasters in the world from 1900 to the present. The database is compiled from various sources, including UN agencies, NGOs, insurance companies, research institutes and press agencies. They present the trends of technological disasters by continent, including the numbers of people killed and affected.

2.6 Vulnerability to food insecurity

A number of organizations have been working on food security projects since the early 1990s. Much of this work concentrates on people in Africa who are particularly vulnerable to food insecurity because of low agricultural productivity.

2.6.1 Vulnerability Analysis and Mapping (VAM) -World Food Programme

As a multilateral agency involved in the provision of project food aid and emergency food aid to developing countries, the World Food Programme (WFP) differentiates the need for food aid between

populations and areas. The past decade has witnessed a number of conceptual, technical and organizational developments in relation to food-related vulnerability. These have resulted in the concept of vulnerability, and approaches to it, being refined and also to an increased interest in the spatial distribution of vulnerability. Mapping locates the geographic area where people are vulnerable to food insecurity. This approach was pursued using up to date data and GIS technology (WFP 1999).

2.6.2 Famine Early Warning System (FEWS) by USAID
FEWS vulnerability assessments evaluate components of national and household food security to identify which people are food insecure and where they are, the nature of their problems, the factors that would influence their food security, and possible interventions. This information is used to help decision-makers take knowledgeable, timely decisions about what types of action are required to protect or improve the food security of a population. The outcome is a classification of populations living in different areas by degree of food insecurity - a first screening for targeting assistance, including food aid (USAID 1999).

2.7   Human insecurity

Studies of human insecurity aim to provide interdisciplinary and integrative perspectives on the relationships between environmental change and vulnerability.

2.7.1 The Global Environmental Change and Human Security (GECHS) Project Office - University of Victoria
GECHS, at University of Victoria, Canada, is the result of several years of discussion, research, and policy initiatives in the broad area of environment and security. As a core project of the International Human Dimensions Programme on Global Environmental Change (IHDP), GECHS arose from the nexus of two seemingly different areas of study: the human dimensions of environmental change and the reconceptualisation of security. The project developed an Index of Human Insecurity (IHI) to distinguish countries on the basis of their level of vulnerability or insecurity, and to group together those countries that possess similar levels of insecurity. This identified the main regions of ecological stress and human vulnerability. Twelve indicators were grouped in six major categories (Lonergan 2000).

2.8   Climate change impacts
People will become more and more vulnerable as a result of the impacts of climatic change such as extreme temperature or, in coastal areas, sea level rise. A number of international organizations are working on climate change and the vulnerability of people to such change.

2.8.1 United Nations Environment Programme
UNEP launched a process on the assessment of vulnerability to climate change by organising an international workshop in October 1999. The process is intended to ensure that methodologies for assessing vulnerability to the adverse effects of climate change, and adaptability to climate change impacts, including an index of vulnerability, will meet the needs of the UN Framework Convention on Climate Change (UNFCC) and address the commitments of subsequent protocols. The work is being undertaken pursuant to Article 4.4 of the UNFCCC, which states, "The developed country Parties shall also assist the developing country Parties that are particularly vulnerable to the adverse effects of climate change in meeting the costs of adaptation to those diverse effects." When it enters into force, the Kyoto protocol, in Article 12.8, further specifies that some of the assistance

required would come from "a share of the proceeds from certified project activities" (UNEP 2000).

UNEP has also recently published a new briefing paper (UNEP 2001) on vulnerability to climate change, specially for policy makers. Its purpose is to review emerging and existing concepts of vulnerability and adaptability to enable them to be refined as dependable tools for effective use by policy makers. The paper provides guidance for cost-effective policy decisions in a variety of countries and regions likely to experience adverse effects of climate change.

2.8.2 Intergovernmental Panel On Climate Change (IPCC)

The IPCC special report "Regional Vulnerabilities to Global Climate Change" explores the potential consequences of changes in climate for ten continental- or sub continental-scale regions. Because of the uncertainties associated with regional projections of climate change, the report assesses the sensitivities and vulnerabilities of each region, rather than attempting to provide quantitative predictions of the impacts of climate change. The report defines vulnerability as the extent to which climate change may damage or harm a system; it is a function of both sensitivity to climate and ability to adapt to new conditions.

The report provides, on a regional basis, a review of the latest information on the vulnerability of ecological systems, socio-economic sectors (including agriculture, fisheries, water resources and human settlements) and human health to potential changes in climate. It assesses the vulnerability of natural and social systems in major regions of the world. In a number of instances, quantitative estimates of climate change impacts are cited (IPCC 1997).

2.8.3 US Global Change Research Information Office (GCRIO)

The US Global Change Research Program (USGCRP) established the National Assessment "to analyse and evaluate what is known about the potential consequences of climate variability and change for the Nation in the context of other pressures on the public, the environment, and the Nation's resources." The Office prepared a report on *Climate Change Impacts on the United States*, which describes tools for assessing climate change impacts. Three tools were used to examine the potential impacts of climate change on the US: historical records, comprehensive state-of-the-science climate-simulation models, and vulnerability analyses for climate change. These three tools were used because prudent risk management requires consideration of a spectrum of possibilities.

Such assessments of vulnerability are important because of the broad spectrum of impacts of global climate change, ranging from positive to negative, depending on the social and geographical environment (GCRIO 2000).

Part 3: Vulnerability Assessment: Approaches, indices and issues

3.1 Introduction

Human systems and the environment are dependent on one another. Risks to the environment will eventually translate into risks to humans because of their dependence on the natural environment for resources. In turn, the environment is susceptible to both natural events and management by humans. This means that measures of overall vulnerability should include measures of both human and natural systems and the risks which affect them. There has been a proliferation of work on vulnerability assessment. Most approaches have involved statistical analysis, the development of composite indices and the use of Geographic Information Systems (GIS).

3.2 Statistical data approach

Most of the international organizations working on vulnerability use the statistical data and techniques such as correlation, regression, normalisation, composite indexing and cluster analysis to identify vulnerable people.

Analysis is generally based on aggregated data from different countries, but highly disaggregated data are required for better analysis.

The Committee for Development Policy (2000) used a statistical approach. By using variables through normalisation and average with equal weights for each countries it constructed the composite index for 128 developing countries. *The Caribbean Development Bank* (2000) also used the same statistical approach for their variables to normalisation and for combining with equal weights to form the composite index.

The United Nations University (2000), The Commonwealth Secretariat (2000), *South Pacific Applied Geosciences Commission (2000), Human Security Project of University of Victoria (1998)* used statistical normalisation and an equal weighting process for vulnerability assessment through a composite index.

3.3   GIS-based mapping approach

Geographic Information Systems (GIS) use statistical and spatial tools to answer 'who, where and why' questions about food-insecure and vulnerable people. Although in many developing countries the data generated are usually integrated in the form of tables, graphs and/or charts, maps have the advantage of presenting data in an easily accessible, readily visible and eye-catching manner. The maps can combine information from different sectors to provide an immediate comprehensive picture of the geographical distribution of vulnerable groups at sub-national level. By providing a visual overview of the major issues affecting food security and vulnerability, the maps highlight gaps and shortfalls in information and thus areas needing attention. A GIS-based approach is helpful for highly disaggregated data; it can easily perform statistical analysis as well as graphic presentation.

Food and Agricultural Organization (1998) developed Food Insecurity and Vulnerability Information and Mapping Systems (FIVIMS) that can assemble, analyse and disseminate information about the problem of food insecurity and vulnerability.

GECHS (2000) Project from the University of Victoria used GIS software packages for ranking different countries in terms of a vulnerability index.

Vulnerability analysis and Mapping (VAM) of World Food Programme (1999) prepared composite maps of vulnerability by putting different weights on different indicators. In work related to hurricane Mitch, UNEP-GRID Sioux Falls (1999) prepared an interactive map of Central America showing vulnerability to different natural hazards. (http://grid.cr.usgs.gov)

3.4   Modelling approach (climate change)

The earth's climate is highly complex and mathematical representations, or models, have to be used to simulate past, present, and future climate conditions. These models incorporate the key physical parameters and processes that govern climate behaviour. Once constructed, they can be used to investigate how a change in greenhouse gas concentrations, or a volcanic eruption, might modify the climate. Computer models that simulate the Earth's climate are called General Circulation Models (GCMs). They can be used to simulate changes in temperature, rainfall, snow cover, winds, soil moisture, sea ice, and ocean circulation over the entire globe, through the seasons and over periods of decades. They provide a view of future climate that is physically consistent and plausible, but incomplete. Nonetheless, through continual improvement over several decades, today's GCMs provide a state-of-the-science picture to help understand how climate change may affect the globe.

The US National Assessment Program has derived an estimate of the degree of climate change that would cause significant impacts to natural and human systems (GCRIO 2000), seeking to answer the question "how vulnerable and adaptable are we?" This required sensitivity analyses to determine under what conditions and to what degree a system was sensitive to change. Such analyses are not predictions that such changes will, in fact, occur. Rather, they examine the implications of specified changes.

3.5   Review of recent work on vulnerability indices

As vulnerability is relative, measuring methods depend on the geographic scale and nature of the assessment, which may encompass environmental vulnerability, disaster vulnerability, food insecurity, etc. Appendix A, based mainly on an unpublished UN paper on vulnerability indices (UN DESA 2000), summarises recent work on vulnerability indices, listing key issues and the indicators and methodologies.

3.6   Issues in vulnerability assessment

Vulnerability is a relative term depending on the nature of the hazard. The scope of studies on vulnerability varies with country coverage, number and type of variables used, methods of scaling, weighting and other methodological factors (UN DESA 2000, unpublished paper). These are briefly summarised below:

3.6.1 Country coverage
Data are not readily available for all countries. The various institutions that have attempted a comprehensive approach have therefore used different criteria to determine where to concentrate their efforts to collect relevant data. In the work of the Committee for Development Policy, for example, additional effort was focused on the least developed and other low-income countries. Several of these are not included in the work of the Commonwealth Secretariat, the Caribbean Development Bank or UNU. The Caribbean Development Bank, given its regional mandate, has been successful in collecting data for a number of Caribbean economies not included in the work of CDP or the Commonwealth Secretariat. SOPAC has so far examined only four developing island states, including Samoa and Tuvalu, which are not included in the work of the Caribbean Development Bank or UNU (Tuvalu is also not included in the work of the Commonwealth Secretariat). RADIUS took only ten cities as a case study while the GECHS human insecurity study was worldwide. The US National assessment team's climate model study only covers the United States.

3.6.2 Number of variables
The studies using relatively small numbers of variables, CDP, Commonwealth Secretariat, Caribbean Development Bank, and United Nations University, are able to develop indices covering a large number of developing countries. Those using a large number of variables have so far been able to apply their methodology only to a few developing countries. The SOPEC, GECHS and RADIUS work deals mostly with environmental variables. Using a large number of variables tends to result in a composite index, which resembles a statistically normal distribution and may thus not reflect the high vulnerability which some countries face with respect to particular risks. A list of the variables used by various organizations is included in Appendix A.

3.6.3 Similarities and differences in selection of variables
When considering the environmental dimensions of vulnerability, whether for an environmental or an economic vulnerability index, all of the studies reviewed here use some measure of vulnerability to natural disasters and food security. Most use some direct measure of the impacts of disasters, SOPAC uses purely meteorological or geological variables, CDP uses an indirect measure (instability of agricultural production), and RADIUS uses economic and planning variables. Other variables used by several research groups to capture a dimension of environmental vulnerability and/or economic vulnerability is the ratio land area and population density.

Some of the studies of vulnerability indices reviewed (for example the World Economic Forum (2000) and the Human Insecurity project of University of Victoria) included socio-economic parameters.

When considering economic vulnerability and geographic vulnerability indices, some of the studies used measures of external trade concentration and/or dependence. Only the Caribbean Development Bank used measures of financial dependence and a measure of dependence on imported energy. CDP, RADIUS and the Commonwealth Secretariat used population size.

3.6.4 Other methodological issues
<u>Scaling of variables</u>: Most studies use similar approaches to normalising and scaling variables, using maximum and minimum values to create indices between 0 and 100. SOPAC, however, normalises the variables to integer values from 1 to 7 and GECHS normalise their variables between 1 and 10.

<u>Weighting</u>: Most exercises use equal weighting, although some with a large number of variables first combine several variables into a smaller number of 'factors' or 'components' thus implicitly giving different weighting to variables depending on the number of variables in each factor. SOPAC assigns explicit weights to differentiate – among its large number of variables – those considered to be of low, medium, and high importance. The Commonwealth uses a combination of weights derived as a first stage from regression analysis (which uses different equations for small and large states) and as a second stage by using principal component analysis. RADIUS uses different weighting system according to the importance of the variables.

3.6.5 Country rankings
A composite index usually combines some measure of the current situation with some measure of the possible economic or environmental situation following a disaster into a single number. It also establishes a ranking among countries, facilitating a comparative analysis. It is a powerful tool for identifying vulnerable countries, which will help policy-makers to make more appropriate decisions. In view of the foregoing, it would be premature to recommend any of the existing indices as a 'stand alone' index of vulnerability suitable as a basis for drawing strong policy conclusions. When considered together with other quantitative and qualitative indicators, they may, however, play a useful role in assessing vulnerability and its policy implications.

3.6.6 Scope for further work
Of the different vulnerability studies reviewed here, those of the CDP, the Caribbean Development Bank and UNU contain elements that suggest the possibility for further refinements in the CDP economic vulnerability index. The EM-DAT natural disaster database of the Centre for Research on the Epidemiology of Disasters (CRED) can be used for disaster vulnerability assessments about which some people have raised criticisms in the past. The UNU approach to a geographic vulnerability index, using four variables, might be an alternative to agricultural instability, presently used by CDP as an indirect measure of economic vulnerability to natural disasters.

Collaboration in data collection between the CDP Secretariat and the regional organizations, CDB and SOPAC, could increase the data coverage of developing island countries.

The RADIUS methodology could be used for combining economic and environmental vulnerability. It offers a new way of aggregating economic, social and environmental parameters.

For global human vulnerability assessment, the variables and methodology should be simple, like the human development index. Risk and coping variables should be included in deriving such new vulnerability indices.

Part 4: Vulnerability and coping capacity

4.1 Introduction

Who are the most vulnerable people - those exposed to a hazard, those who do not have the ability to cope with the risk, or a combination of both? It is important to prioritise risks in order to identify the most vulnerable people and their geographical distribution. Vulnerability should be ranked according to the most serious consequences. Such information is essential for decision-makers for optimal use of limited resources.

Every year thousands of people die as a result of a range of disasters but the fate of many of them is never reported globally. The latest disaster report of the International Red Cross Federation (2000) showed that in 1999 the death toll from infectious diseases (such as HIV/ AIDS, malaria, respiratory diseases and diarrhoea) was 160 times the number killed in natural disasters, including the massive earthquakes in Turkey, floods in Venezuela and cyclones in India. The situation is getting worse. It is estimated that over the next decade, HIV/AIDS will kill more people in sub Saharan Africa than all the wars of the 20th century. Table 4.1 shows the reported number of people killed by different type of phenomenon in the different continents
.

Table 4.1: Total number of people reported killed, by continent and by type of phenomenon (1990 to 1999)

Phenomenon	Oceania	USA & Canada	Rest of Americas	Europe	Africa	Asia	Total
Slides	279	-	2 010	644	225	5 500	8 658
Droughts	98	0	-	-	12	2 680	2 790
Earthquakes	70	63	3 456	2 395	816	91 878	98 678
Epidemics	115	138	11 985	411	57 082	14 316	84 047
Extremes temperatures	27	1 218	780	954	102	5 974	9 055
Floods	30	363	35 235	2 839	9 487	55 916	103 870
Wild Fires	8	41	60	127	79	260	575
Wind Storms	262	1 718	11 546	913	1 612	185 739	201 790
Volcanoes	9	-	77	-	-	994	1 080
Other Natural Disasters*	2 182	-	15	-	-	489	2 686
Non-Natural Disasters**	534	-	12 353	7 832	16 136	42 453	79 308
TOTAL	3 614	3541	77 517	16115	85 551	406 199	592 537

*Source: IFRC World Disaster Report 2000 *Insect Infestations, Wave/Surge ** Industrial, Transport and Misc Accidents*
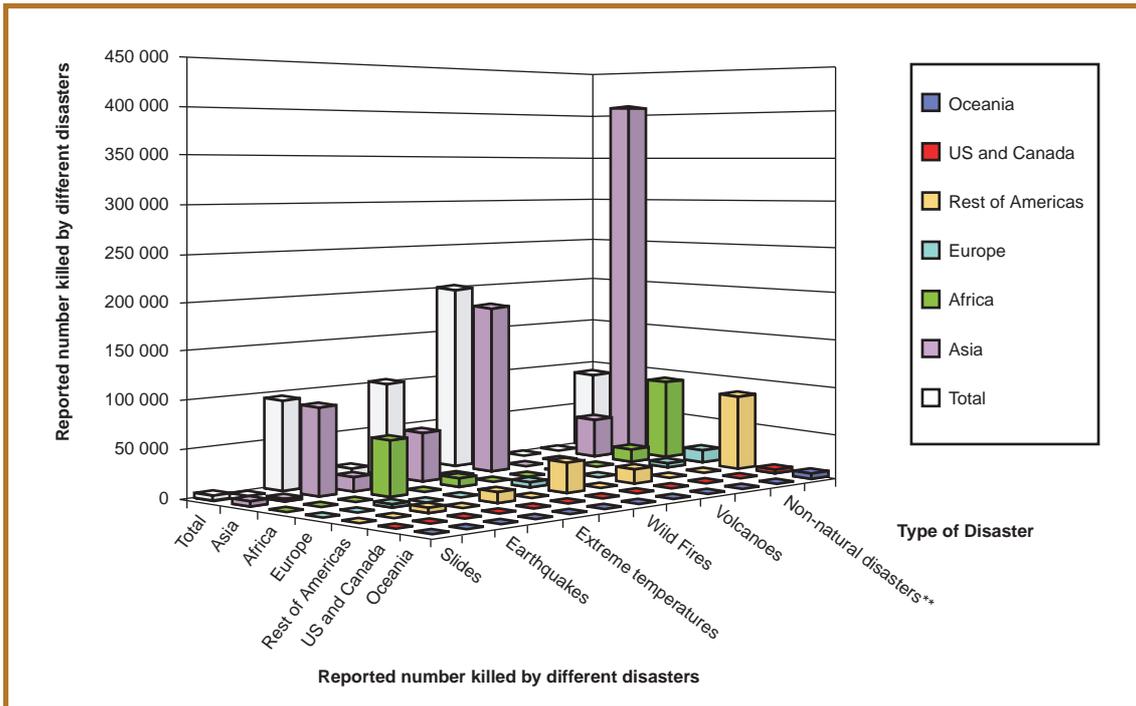
Figure 4.1: *Total number of people reported killed, by continent and by type of phenomenon (1990 - 1999)*

Figure 4.1 shows the same information in a diagrammatic form comparing the fatalities between the different continents. The United States and Canada are shown as one continent as they are among the two richest countries in the world consisting land and resources (also physically joined). Asia and Africa are particularly vulnerable, with more fatalities than elsewhere. In last 10 years windstorms killed thousands of people in Asia, 13 times more than in rest of the world. Africa is the most vulnerable to epidemics rather than any other disaster, unlike the situation in other regions.
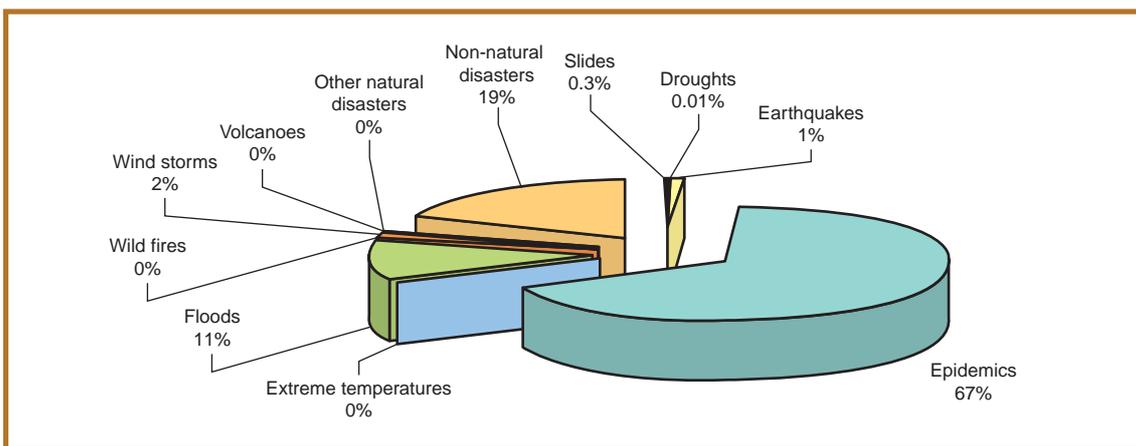
Figure 4.2: *Percentage contributions of different phenomena to the total death toll of extreme events in Africa (1990 - 1999)*

Figure 4.2, based on Table 4.1, illustrates the percentage contributions of different phenomena to the total death toll of extreme events in Africa. An analysis of the results shows that the high death tolls in the Asian continent are due to high population density. Table 4.2 shows the relationship between the number of disaster events and fatalities in Bangladesh, India and the United States.

Table 4.2: Number of reported natural disaster events and fatalities in selected countries (1990 - 1999)

Country	Number of reported Events	Persons killed
USA	242	3 418
India	114	50 777
Bangladesh	86	150 242

Source :CRED 2000 Dataset
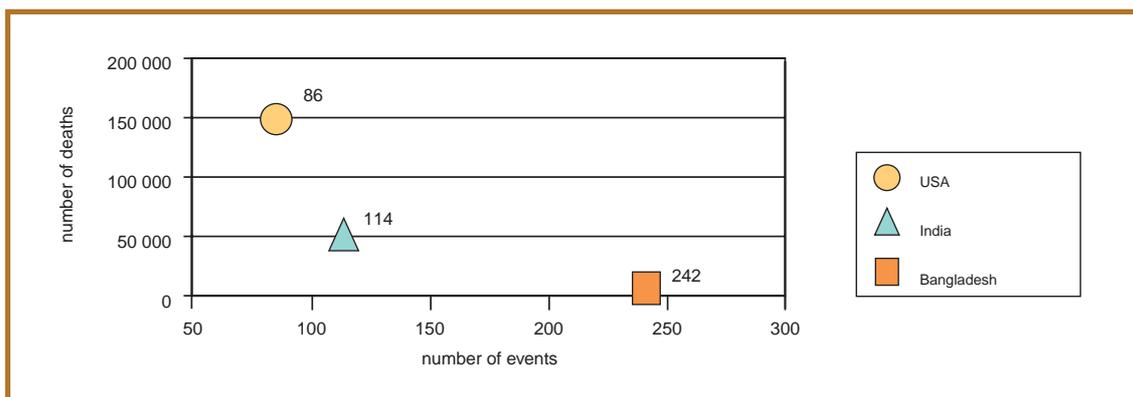
Figure 4.3: *Number of disaster events and fatalities in selected countries (CRED 2000)*

Figure 4.3 shows the same information in diagrammatic form where the number of reported disaster events in the United States was more than twice that in India and about 3 times that in Bangladesh. However, the number of deaths in India was 14 times higher than in the United States, whereas in Bangladesh the number of deaths was 34 times higher. This demonstrate that exposure to extreme events is not the only reason for vulnerability. A hurricane in the US may miss population centres and cause no deaths whereas a cyclone in Bangladesh is highly likely to result in loss of life because of the much higher population density.

In a recent Stanford University study on earthquakes, Davidson (1997) showed that the earthquake disaster risk in Jakarta was about the same as in San Francisco, but significantly less than in Tokyo. Further analysis indicated that while the risk in Jakarta was mostly the result of the vulnerability of the infrastructure and insufficient emergency response and recovery capability, that in San Francisco was due primarily to the high frequency of earthquakes, and that in Tokyo was driven by the very large number of people and structures exposed.

4.2   Different dimensions of vulnerability

Recent news items about disasters in the Indian sub-continent and the United States also shows the different dimension of vulnerability

The Washington Post ,August 17, 2000
Governor Calls Montana A Fire Disaster Area
By Shannon Dininny

HAMILTON, Mont., Aug. 16 — The governor declared the entire state of Montana a disaster area today as authorities issued a new evacuation order for part of the burned, smoke-choked Bitterroot Valley. Montana's 25 largest active fires accounted for nearly half of that total acreage, the agency said. So far this year, more than 2 000 fires have burned 184 941 hectares statewide. Fires had burned more than 107 241 hectares in the Bitterroot area of the state's southwestern corner. In the past six weeks, fires have blackened more than 222 577 hectares of Idaho forest and range.

The Washington Post , August 15, 2000
South Asia Soaked by Monsoon Flooding
By Rama Lakshmi

NEW DELHI, Aug. 14 — South Asia's annual monsoon rains bring annual floods and tales of disaster. But as this year's rains inundate northern India, Bangladesh and the Himalayan region, the emerging picture of destruction appears worse than usual.

Flooding in the Ganges and Brahmaputra river systems has killed an estimated 300 people across four countries and forced more than 6 million from their homes in India alone. So far, the intensity of rains and the death toll are less than in 1998, the worst recent year for monsoon flooding, but the rains are likely to last another six weeks.

Much of the death from seasonal floods is caused by diseases such as cholera and dysentery that tend to emerge as the waters recede, so the ultimate toll remains difficult to predict.

Officials said thousands of marooned villagers in Bihar, one of India's poorest states, had refused to move to relief camps, fearing their farm animals and belongings would be stolen.

These reports illustrate the gap between rich and poor country in terms of risk. Although the United States is vulnerable to frequent wild fires, loss of property and life is relatively minimal. In the Indian sub-continent, large numbers of people loose their life and livelihood every year due to various disasters because of abject poverty and high population density.

The reports also expose a usually hidden aspect of vulnerability. Although some people are vulnerable to disaster, that may not be their main concern. They are so poor that they could not survive if their property were stolen. For such people the long-term loss of 'whatever little they have' is even more serious than the immediate impact of natural disasters. This is sometimes also true in 'developed' countries, where people may be reluctant to leave their homes until they are forced to do so.

Another study from the World Bank shows that the burden of diseases, as measured in loss of Disability Adjusted Life Years (DALY) varies considerably from region to region. Table 4.3 shows that water supply and sanitation problems pose the largest threat to human health in many areas of the world.

Table 4.3   Burden of diseases from major environmental risks

Percentage of DALY in each country group						
Environmental health group	Africa	India	China	Asia & Pacific	Latin America	Less Developed Countries
Urban air pollution	1	2	5	2	3	2
Malaria	9	0.5	0	1.5	0	3
Agro-industrial waste	1	1	1.5	1.5	2	1
Indoor air pollution	5.5	6	9.5	4	0.5	5
Water supply & sanitation	13	11	4.5	10	7	9
All causes	29.5	20.5	20.5	19	12.5	21

Fig 4.4   Burden of diseases from major environmental risks as percentage of all causes for Africa, which shows water supply and sanitation plays major role for loss of DALY.
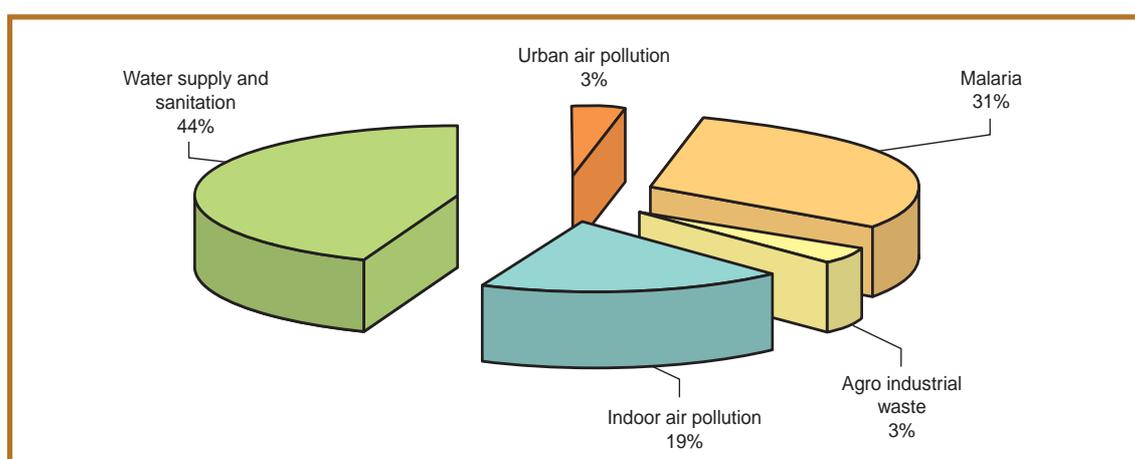
Figure 4.4: *Burden of diseases from major environmental risks as percentage of all causes for Africa*

Source: The World Bank 2000

4.3   Vulnerability depends upon coping capacity

Coping means ability to withstand risks at a particular point of time. Such ability can result from money, deployment of technology, infrastructure or emergency response systems. Coping is also the manner in which people act within existing resources and ranges of expectations to achieve various ends. In general, this means the ability of people to respond to unusual, abnormal, and adverse situations. Thus coping can include defence mechanisms and active ways to solve the problems. Table 4.4 and figure 4.5 suggests an inverse relationship between per-capita income and fatalities for selected countries.

Table 4.4   Relationship between per capita income and fatalities (1970-1999) for selected countries

Country	Per-capita income	People killed due to natural disaster (1970 - 1999)
Bangladesh (1)	360	171 789
India (2)	370	99 433
Honduras (3)	740	65 47
Guatemala (4)	1 580	24 134
Peru (5)	2 610	3 899
Turkey (6)	3 130	27 334
Mexico (7)	3 700	14 818
USA (8)	29 080	9 547
Japan (9)	38 160	8 335

Source: CRED 2000 and UNDP 2000
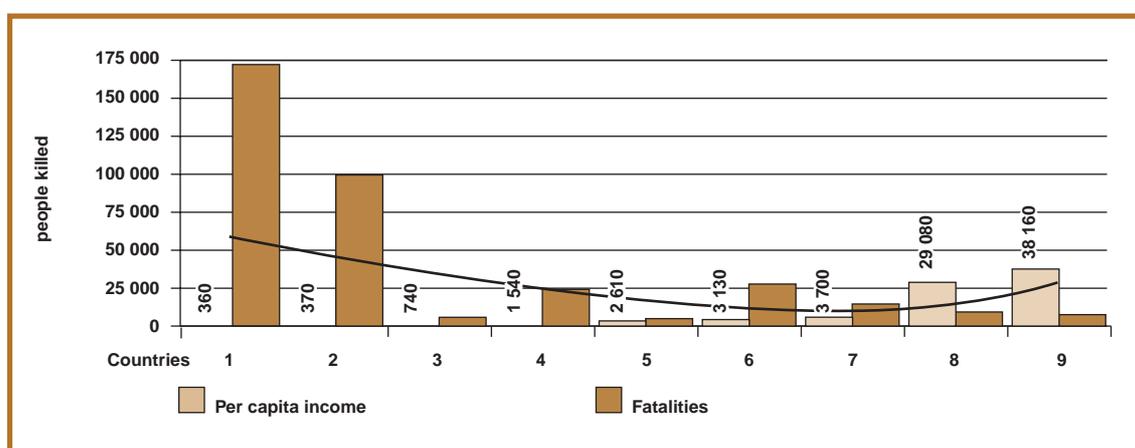
Figure 4.5: *Graph showing the relationship between per capita income and fatalities*

These results suggest that rich countries with high per capita income have low rates of fatalities due to disasters because of their better coping capacity (and population density in some cases), while poorer countries have higher rates due to inferior coping capacity.

A similar relationship is observed between life expectancy (*Disability adjusted life expectancy, DALE)* and per-capita income, showing the importance of economy for healthy environment. Usually people having good per capita income have more resources to develop a healthy environment and they also have better access opportunity than developing countries. People of rich countries live longer than developed countries because of healthy environment.

Table 4.5   Per-capita income and DALE for selected countries

Country	Per capita income	Disability adjusted life expectancy (DALE)Total population at birth
Bangladesh	360	49.9
India	370	53.2
Honduras	740	61.1
China	860	62.3
Morocco	1 260	59.4
Guatemala	1 580	54.3
Peru	2 610	59.4
Turkey	3 130	62.9
Mexico	3 700	65
USA	29 080	70.5
Japan	38 160	74.5

Source: WHO 2000 and UNDP 2000

Table 4.5 shows the positive relationship between per capita income and life expectancy. Rich countries have higher life expectancy rate mainly because people with high per-capita income have access to better health facilities.

Thus coping capacity is, generally speaking, dependent upon the level of economic development of a country. A high level of economic development is generally related to access to opportunities, which can enhance the ability of persons or groups to anticipate, cope with, resist, and recover from the impact of any risk or hazard to which they may be exposed.

To sum up, the human vulnerability can be defined as the exposure to hazard by external activity (e.g. the climatic change) and coping capacity of the people to reduce the risk at a particular point of time. So, vulnerability can be expressed as a function of exposure to hazard, population density and coping capacity over time.

Part 5: Human vulnerability to environmental change

5.1 Introduction

The increasing vulnerability of humans to environmental change is a major concern.

In fact, the World Commission on Environment and Development (WCED 1987) called to address the following:

- Identifying critical threats to the survival security or well-being of all or majority of people, globally and regionally;
- Assessing the causes and likely human, economic, and ecological consequences of those threats, and reporting regularly and publicly on their findings.

The United Nations Conference on Environment and Development, which adopted Agenda 21 in 1992 proclaimed that *"Human beings are at the center of concerns for sustainable development. They are entitled to a healthy and productive life in harmony with nature"* (United Nations 1993).

However, most scientific assessments of global environmental change have paid most attention to the analysis of environmental change itself, overlooking the impact these changes might have on ecosystems and societies. As understanding of environmental change throughout the world grows, it is increasingly clear that highly vulnerable regions, peoples, and ecosystems will bear much of the burden of current patterns of unsustainable human activities. Hence issues related to the vulnerability of social and ecological systems are emerging as a central focus of policy-driven assessments of global environmental change (Belfer Center for Science and International Affairs 2000).

There is a significant difference between vulnerability assessment and traditional approaches to impact assessment. Basically, impact assessment selects a particular environmental stress of concern (e.g. climate change) and attempts to identify its most important consequences for a variety of social or ecosystem properties. Vulnerability assessment, in contrast, chooses a particular group or unit of concern (e.g. indigenous people, coastal communities) and tries to determine the risk of specific adverse outcomes for that unit in the face of a variety of stresses and identifies a range of factors that may reduce response capacity and adaptation (Belfer Center for Science and International Affairs

2000). In the past, assessments of environmental effects have dealt principally with characterising the major types of damage likely to ensue from environmental degradation and providing estimates of their aggregate magnitudes. But much of this assessment has been geared to single environmental stresses and has generally not addressed the multiple stresses confronting the most vulnerable peoples or the social and economic factors, such as poverty, that shape their abilities to cope with continuing environmental degradation and perturbations.

5.2 A Framework for Assessing Human Vulnerability

Human impact on the environment should not be seen just as a one-way process. There is feedback. Changes in the environment have an impact on human welfare. These impacts in turn produce a human response- often an alteration of behaviour to reduce the problem (Harrison and Pearce, 2000). Hence a broader framework for assessment would be one that quantifies human impact on the environment and then assesses how changes in environment would increase human vulnerability. Such a process should lead to more societal commitment to the environment, which should in turn reduce human pressure on the environment (see Figure 5.1 below)
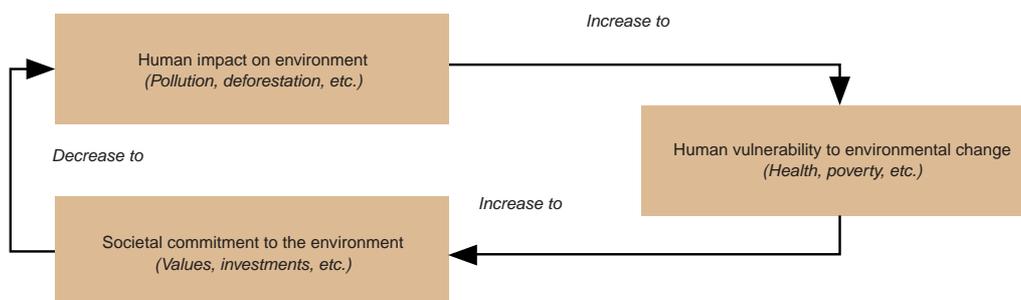
Figure 5.1: An overall framework for environmental assessment

Figure 5.2 gives an overall representation of human vulnerability to changes in the environment. It suggests that there are three main contributory factors: hazard, exposure, and coping capacity. Each of these is disaggregated into the more specific factors that comprise it. For simplicity, it does not show interactions among the factors, or a further important factor, population density.
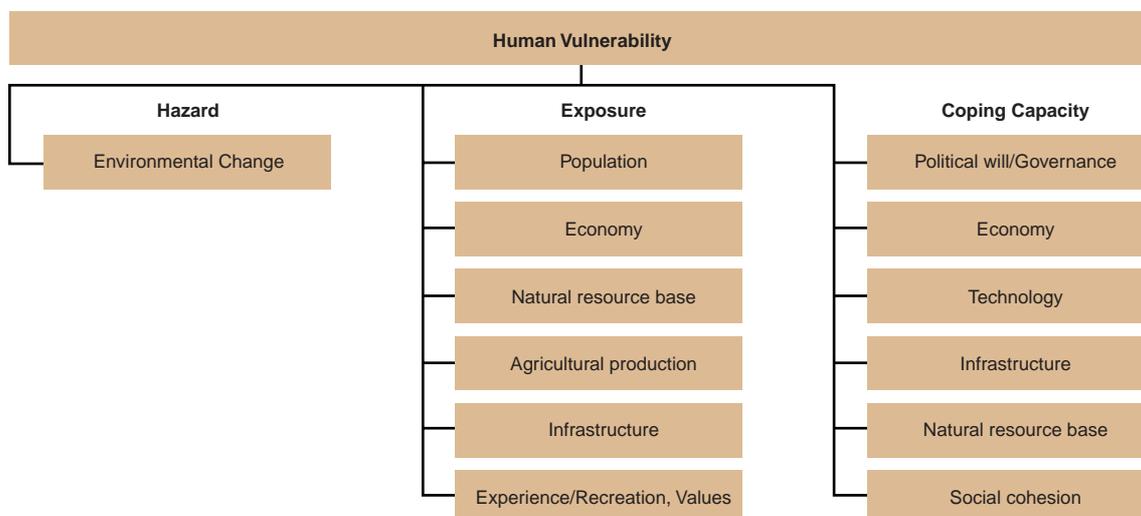
Figure 5.2: An overall diagrammatic representation of vulnerability

Most environmental analysis is normally organised around resources - climate, water, forests, biodiversity, pollution, etc. - rather than human concerns. It is vital to establish relationships which can both illustrate the degradation of the environment and indicate the possible consequences to people of such degradation.

Such analysis could be organised around many different themes. Vulnerability can be classified as economic, social, ecological or institutional. Eight different themes through which human welfare is normally affected by environmental degradation are*: Damage to Health, Economic Loss, Poverty, Food Insecurity, Loss of Intellectual Property Rights (IPR), Loss of Natural Heritage, Conflict, and Vulnerability Impacts of Extreme Events/Natural Hazards and Climate Change* (Figure 5.3). Discussing human vulnerability around these rather than around environmental state variables such as resources or pressures would have greater resonance for the public.

Eight themes for human vulnerability to environmental change							
Damage to Health	Economic losses or gains	Poverty	Food insecurity	Loss of natural heritage and experiences	Loss of IPR	Conflict	Extreme events, climate change impacts

Figure 5.3: *Human vulnerability in different themes*

A summary of issues on each of these themes is given below.

Health: Environmental damage has serious consequences for human health whether it is water or air pollution, waste and sanitation. Water pollution and contamination impact people worldwide. In industrial countries the major health concerns are about the effects of toxic chemicals and minerals, such as pesticides and lead in drinking water. In developing countries water borne diseases are predominant. Air pollution from industrial emissions, car exhaust and the burning of traditional fuels kill a large number of people yearly: mainly people die from respiratory damage, heart and lung diseases and cancer. There is a need to separate the impact of "environmental diseases" - waterborne diseases and health impacts of climate change in air, and water pollution including exposure to toxic chemicals, hazardous wastes - from the data available for the burden of diseases.

Economic losses: Economic growth is often directly linked to increasing exploitation of natural resources. Environmental damage such as environmental pollution, soil erosion, deforestation, land degradation, water shortage, etc. causes productivity losses. For example, in most countries energy use continues to rise because consumption has increased faster than efficiency. As a result pollution besides harming human health causes direct economic losses in agricultural production (Speth 1999). The standard method of measuring productivity is through adjusted national income accounts related to renewable resources. An alternative approach is to look at the economic losses/ cost of remediation. Data on resource losses could be integrated into a national income account framework.

Poverty: Environmental changes almost always have a greater impact on those who live in poverty. About one third of world's population, the majority of which are poor, depend directly on what they can grow, catch or gather. Therefore, the poor are especially vulnerable to degradation of natural

systems. Global concerns such as the changes in earth's atmosphere are critical for the livelihoods of poor people, and their consequences last longer than first assumed. For example, a rate of climate change is likely to cause widespread economic, social and environmental degradation over coming decades. Hence, the poorest people of developing world are to be hit the most by the failing harvest, growing water shortages and rising sea level. The vast majority of people who die each year from air and water pollution are people living in poverty in developing countries. Also, commonly, all around the world, poor people live the closest to dirty factories, busy roads and waste dumps (Speth 1999). There is no single commonly accepted methodology for looking at the impact of resource degradation on poverty. However, it could be divided into such categories based on accessibility of the poor to water, land resources and food security.

Food security: Food security can be defined as the state in which all persons obtain a nutritionally adequate, culturally acceptable diet at all times through local non-emergency sources. It broadens the traditional concepts of hunger, embracing a systemic view of the causes of hunger and poor nutrition within a community while identifying the changes necessary to prevent their occurrence. In many cases, the environmental price of food production is the loss of natural vegetation and biological diversity, soil erosion, and surface and groundwater depletion. Inevitably, there are divergent views about how land should be used, whether for industrial crops, food, nature conservation or industry. Clearly defined procedures are needed to satisfy different needs and interests in society, not only of current generations but also taking into account future needs. This means involving stakeholders, farmers, local land managers, non-governmental and governmental organizations, consumers and others, and evaluating the environmental costs of different land use options (Umrani and Ali Shah 1999).

Loss of natural heritage and experiences: The ethical and religious beliefs of cultures around the world include respect for and protection of nature. For many people, the diversity of life is also part of their spiritual and cultural heritage, and nature is an unsurpassed source of relaxation, wonderment, rejuvenation, beauty and peace. Globally, the loss in natural heritage diversity has become so rapid and severe that can be compared to the great natural catastrophes. The significant and increasing loss of biodiversity and natural heritage areas have created widespread global concern. It is not difficult to inspire in people a desire to protect nature and feel that the world would be a poorer place if wildlife and pristine areas disappeared. People in the West and the growing middle class in the developing world want to use whatever influence they have to protect nature for future generations and overall human well-being.

Loss of intellectual property rights (IPR): Intellectual Property Rights are rights to make, use, and sell a new product or technology that are granted, usually for a period of 17- 20 years, solely to the inventor or the corporation which files a claim on the inventor's behalf. They generally take the form of patents, trademarks, or copyrights and have traditionally fallen under the domain of national law. Different countries have produced different IPR laws, each one a balance between industry's desire to capitalize on its investments in technological development and the rights of society to benefit from the knowledge and resources of its country.

The issue related to the Loss of IPR is a major concern in the Convention on Biological Diversity (CBD). The Convention on Biological Diversity establishes important principles regarding the protection of biodiversity while recognizing the vast commercial value of the planet's store of germplasm. However, the recent expansion of international trade agreements such as World Trade Organization (WTO)'s General Agreement on Tariffs and Trade (GATT) and Trade-Related Intellectual Property Rights (TRIPs) establishing a global regime of intellectual property rights creates incentives that may destroy biodiversity, while undercutting social and economic

development opportunities as well as cultural diversity. These rules will supersede national laws and allow privatization of the world's knowledge and resources. The ability of companies to gain monopolies over what were formerly freely available community resources — seeds, plants and even micro-organisms — will have devastating effects on both human communities and the protection of biodiversity (Dawkins et al 2001).

The matter is likely to intensify in future with increased globalization. Indigenous communities in developing countries are likely to be more vulnerable due economic loss of the Patent Rights of medicinal plants to the western drug companies. In fact, in the developed world corporations are increasingly converting IPR into substantial wealth (for example Microsoft, Intel etc).

Conflict: Recent empirical research has linked conflict - and the potential for such conflict - to environmental problems such as water pollution, over-fishing, deforestation, and global warming. The environmental conflicts may take the form of violent clashes between and within nations over particular renewable resources such as freshwater and fish stocks. They may also engender and interact with other economic and social factors such as poverty and weak states. - to foster conflict between and within nations. If environmental stress can, in fact, contribute to conflict within and between nations, then even the staunchest of mainstream security analysts must recognize that human vulnerability is intimately tied to environmental issues. Efforts to reduce human vulnerability to conflict should increasingly focus on the roots of this scourge and empirical research suggests that reducing environmental stress may be an effective strategy for achieving this goal.

Extreme events/natural hazards/climate change impacts: This refers to the occurrence of extreme events/natural hazards, including climate change, and their impacts on human beings and infrastructure. There is the increasingly strong evidence for humanity's influence on the global climate. This fact leads to changes in weather patterns, water resources, the cycling of the seasons, ecosystems, extreme climate events, and much more. These trends are expected to continue through the 21st century and beyond. The least developed countries are the most vulnerable due to their lack of planning and poor preparedness. Future ability to satisfy human needs will be affected – both positively and negatively – by changes in agricultural conditions; by local and regional trends in droughts, floods, and storms; by unforeseen stresses on buildings and other long-standing infrastructure; by altered disease and health risks.

Hence, the concept of vulnerability needs to be broadened to encompass increased uncertainty caused by resource degradation. Such uncertainty is caused not only by extreme events, but also by the loss of access to resources by the poor, conflict, policy changes, loss of IPR and trade flows. Vulnerability is a dynamic variable which measures the potential variance of the outcomes related to all these causes. People need better approaches and methodologies to consider and assess these issues.

The framework set out above provides a solid foundation and rationale for the choice of indicators for vulnerability assessment. This framework now needs to be put into practice, to transform it from a theoretical construct into a model that can produce quantitative, directly usable results.

Table 5.1 sets out potential indicators required for assessing human vulnerability to environmental change.

Table 5.1 – Potential indicators for assessing human vulnerability to environmental change

Human vulnerability	Environmental causes	Indicators
Health	- Urban air pollution - Water pollution/sanitation - Toxic chemicals/food contaminants	- Number of people affected by environmental diseases (pollutants, chemicals), microbial infection, diarrhoea, chronic lung diseases - Number of people having access to safe drinking water and sanitation - Loss of DALY (Disability Adjusted Life Year)
Economic losses/gains	- Environmental diseases - Soil erosion - Deforestation - Siltation	- Amount spent on treating environmental diseases - Amount spent on environmental clean up - Food productivity loss due to soil erosion, deforestation, etc. - Loss due to siltation of dams
Poverty	Depletion of natural resource base to meet the basic needs of food, fibre, firewood , income and employment	- Different income categories affected by natural resource degradation - Different income categories affected by air pollution and sea level rise - Different income categories affected by water contamination and lack of sanitation
Food security	- Loss of natural vegetation and biological diversity, - Soil erosion - Surface and groundwater depletion - Rainfall distribution	- Percentage of natural vegetation cover - Percentage of people directly dependent upon land resources - Extent and distribution of degraded land - Freshwater availability - Rainfall variability
Loss of natural heritage and experience	Depletion of natural flora and fauna	- Areas designated as Protected Areas; natural recreation areas - Rate of deforestation - Rate of habitat loss
Loss of IPR	Depletion of endemic species	- Number and distribution of endemic species - Number of Patent Rights
Conflicts	- Scarcity of water - Depletion of natural resource base	- Number of people living in water-scarce areas - Number of people dependent upon vegetation resources
Extreme events/climate change impacts	- Flood, drought, fire, cyclone and other disasters - Global warming/Sea level rise	- Number of people living in disaster-prone areas - Number of people living within the 100 km of coast - Amount of greenhouse gases emission

Time-series data are needed to conduct a comprehensive vulnerability assessment at a national/local level. Unfortunately not many reliable data sets exists to construct many of these indicators. Hence, the use of proxy indicators should be explored. Nested series of studies are also required to assess vulnerabilities at different spatial and temporal scales.

Part 6: Case studies for human vulnerability assessment

Case study 1: Vulnerability to health in Bangladesh

The international media rarely touches on the misery and suffering endured by the hundreds of millions of people in the developing countries who lack access to the basic necessities of life - clean water, adequate food, clothing and housing. Only when malnutrition turns to famine and diseases become epidemics do reports begin to appear, usually written in sensational but superficial terms.

In Bangladesh, a huge social disaster is developing that has received virtually no news coverage. Millions of people in rural areas are being slowly but surely poisoned as they drink from water supplies contaminated with small but nevertheless potentially fatal quantities of arsenic. Naturally occurring arsenic has tainted a 500 km swathe (Fig. 6.1) of rice paddies and banana groves between the Ganges River and the Indian border. This has happened because of a huge tube well programme to provide clean drinking water where none or not enough were available. Unfortunately tapped into soil, the wells contained naturally high levels of arsenic, which fact was not discovered before the programme was launched.
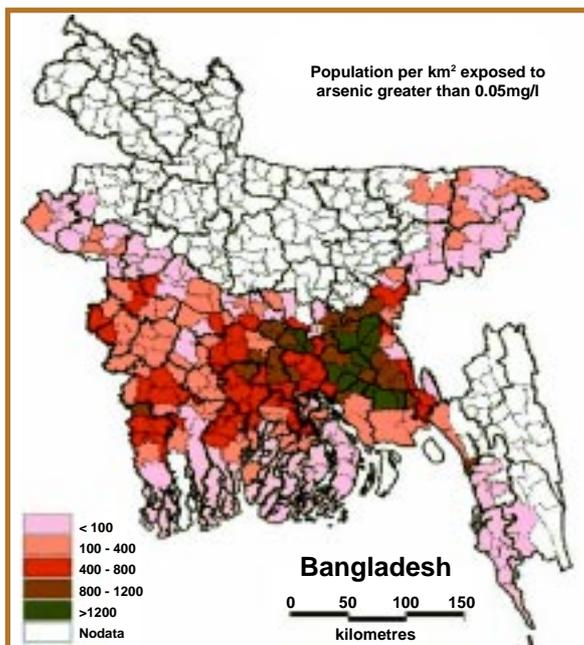
Figure 6.1: People exposed to arsenic threat in Bangladesh

Arsenic is a white, semi-metallic powder, found in nature, that can cause skin cancer, kidney and liver failure, respiratory problems and in some cases death. It has become clear that a significant percentage of the county's four million tube wells - the main source of drinking water throughout Bangladesh - contain dangerous levels of arsenic. People drinking arsenic-contaminated water face serious health risks, including skin diseases, respiratory ailments and cancer. Soil and underground water in southwestern Bangladesh have already been affected by arsenic contamination affecting the health of millions of people. According to the latest research, nearly 75 million people out of the country's total 130 million are vulnerable to the threat. About 24 million have been exposed to arsenic poisoning, and 7,600 arsenic victims have been detected.

According to a UNICEF study, access to safe drinking water in Bangladesh has declined by 17 per cent in the last three years due to arsenic contamination in ground water. Table 6.1 demonstrates the statistics of arsenic poisoning in Bangladesh.

Table 6.1 Statistics of arsenic calamity in Bangladesh

Total number of districts in Bangladesh	64
Total area of Bangladesh	148 393 sq km
Total Population of Bangladesh	130 million
GDP per capita (1998)	US$ 260
WHO arsenic drinking water standard	0.01 ppm
Maximum permissible limit of arsenic in drinking water of Bangladesh	0.05 ppm
Number of districts surveyed for arsenic contamination	64
Area of affected 59 districts	126 134 sq km
Number of affected districts having arsenic contamination	59
Population at risk of the affected districts	75 million
Potentially exposed population	24 million
Number of patients suffering from Arsenicosis diseases	7 000
Total number of tube wells in Bangladesh	4 million
Total number of affected tube wells	1.12 million

Source: Bangladesh Bureau of Statistics, Dhaka Community Hospital, Department of Public Health & Engineering

The World Health Organization (WHO) standard for arsenic in drinking water is 0.01 mg/l. However, in Bangladesh the maximum permissible limit of arsenic in drinking water is 0.05 mg/l. Arsenic concentrations of more than 0.05 mg/l have been detected in 41 of the 64 districts in Bangladesh, representing a population of 76.9 million. The study was carried out by the School of Environmental Studies (SOES), Jadavpur University and Dhaka Community Hospital. Over 45 per cent of the groundwater samples (n=10 405) had arsenic levels > 0.05 mg/l. Out of 23 districts surveyed, 22 districts (population 35 million) had patients suffering from arsenic poisoning. A third of the people examined (n=7 588) had arsenical skin-lesions. In one village where the arsenic level in groundwater was 1.65 g/l, over half of the adults (n=145) and 17 per cent of the children (n=48) had arsenical skin lesions. The highest concentration so far recorded of arsenic in tube wells in Bangladesh is 4.7 mg/l. The worsening contamination of groundwater aquifers and the suffering of millions of people demands immediate action.

Case study 2: Vulnerability to cyclones in India

6.2   Introduction

India is one of the most densely populated countries in the world with one thousand million people. About half of the country's boundary is the ocean. About half of the Indian boundary is surrounded by ocean and approximately 40% of total population lives within 100 km ocean coast (Hua et. al. 2002). These people living in the coastal regions of India are highly vulnerable to natural hazards such as cyclones and man-made hazards like water pollution. The natural hazard takes million of lives, damage properties and natural resources in coastal areas. In spite of cyclone warning systems, a recent cyclone killed over 10 000 people in Orissa states and millions of people became vulnerable (CNN 1999).

South Asia, in general, is one of the world's regions most vulnerable to cyclones. Most generate in the Bay of Bengal and the Indian Ocean. Figure 6.12 shows the development of a cyclone close to the east coast of India. In a recent cyclone in Orissa about 90 to 100 per cent of agricultural crops were damaged.

People in the affected areas lost valuable property and their stores of food and seeds. An attempt has been made to assess the vulnerability of the Indian coast to cyclones. The vulnerability of the region is modelled and the exposed population calculated through a GIS in terms of population density and cyclonic risk.
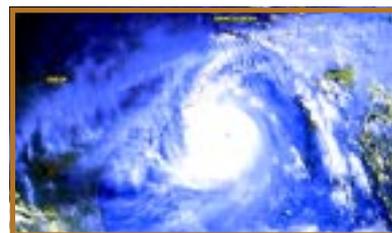
Figure 6.2: Tropical cyclone close to the east coast of India

6.3 Vulnerability in South Asia

Figure 6.3 shows levels of vulnerability to cyclones. Bangladesh, India and Sri Lanka are the countries most affected. A large number of people are killed by cyclones every year, especially in Bangladesh and India. A GIS-based study shows that approximately 91 per cent people in Bangladesh are vulnerable to cyclones of which 14 per cent are extremely vulnerable.

In India approximately 61 per cent people are vulnerable of which 6 per cent are extremely vulnerable. Sri Lanka is also moderately vulnerable.
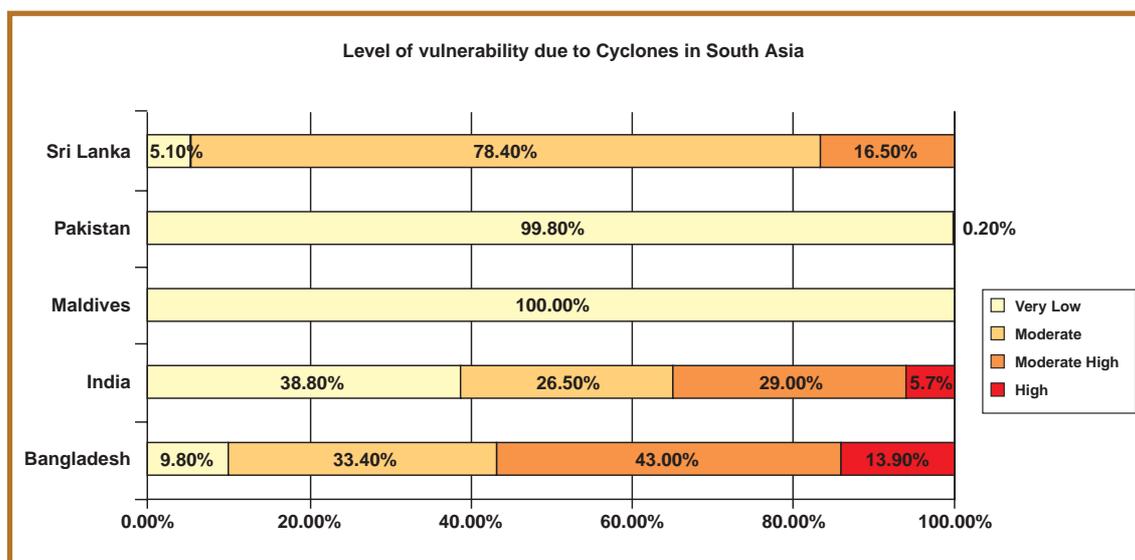
Figure 6.3: *Level of vulnerability due to cyclone in South Asia between 1971-1999 Source Earth Sat 2000*

6.4 GIS for cyclonic vulnerability assessment

A GIS-based approach has been used to assess vulnerability to a single hazard component. The following steps were used to calculate the population in different States of India vulnerable to cyclonic storms:

1. A storm risk map is produced to identify the vulnerable zone using modelling tool, where vulnerability is grouped according to the past trend and intensity of tropical storms (Earth Sat 2000).

2. A grid based (1 sq km) population density map is created combining urban and rural population of India (Earth sat 2000).

3. Vulnerable population of each state of India is calculated by combining the storm risk map and the population density map and state boundary map in a GIS framework.

4. Coping capacity factor (per capita income of each state) is introduced to compare relative vulnerability in different states of India.

The following flow chart shows the method used for cyclone vulnerability assessment :
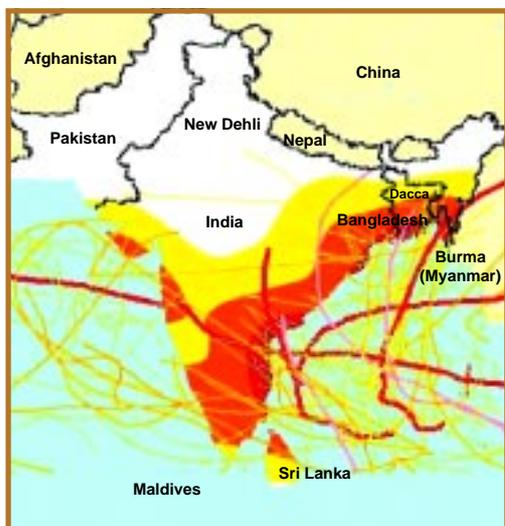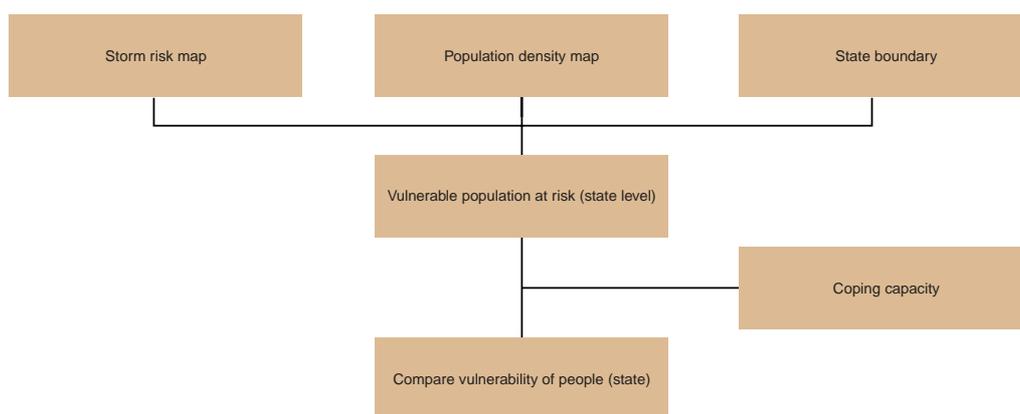
Figure 6.4: Storm risk in India

6.4.1 Methods for cyclone risk model

The storm risk model developed by Earth Satellite Corporation used the following methodology to calculate the storm risk zone in India

Input data

All historical cyclonic storm and tropical depression center tracks data are recorded from 1971 to 1999, which is compiled by Global Tracks (http://www.gtracks.com/).

Storm risk model

The storm risk model mapped the regional historical density of storm intensity from November 1971 to November 1995. The regional line density (within a 500 km distance) of cyclonic storm and tropical depression center tracks was calculated for each 1 km sq. cell in the study area using a weighting factor. The resulting weighted density surface was then categorized into low, low-moderate, high-moderate, and high-risk categories to represent variance in risk especially in costal areas of India. (Earth Sat 2000)

Outputs

The resulting risk surface map (Fig. 6.4) shows the historical (1971 - 1995) risk of cyclonic storms and tropical depressions throughout the study areas, where dark colours represents high risk. The risk surface represents the regional frequency, density, and intensity of cyclonic storm activity.

6.4.2 Methods for population density model

The gridded level (1 sq km) population density surfaces model developed by Earth Satellite Corporation was used in this study to aggregate urban and rural cell level population (Miller 2000).

Input data

Publicly available data and information for urban and rural population served as the source of inputs to this analysis.

Methods

State-level urban and rural population for India was collected through the US Census Bureau International Program in the Department of Commerce. These state-level figures were allocated to 1 km sq. pixels were based on a multi-criteria suitability model (Earth Sat 2000).

The resulting urban and rural population density GRID surfaces were combined in a map (Fig. 6.5) to produce a complete population density per km^2 surface for 1998.

6.4.3 Calculating Vulnerable population at risk

Input Data

Vector-based spatial data (political boundary) of Indian states was obtained from publicly available sources such as Environmental System Research Institute (ESRI) database.

Methods

State level grid map (Fig. 6.6) is derived from state level vector based map. vulnerable population at risk is calculated by combining the storm risk map and the population density map of India. State level population was calculated combining the above map and the state grid map. Total population for different vulnerable region is also calculated for this study. Arc Info GRID module was used for this analysis.

Figure 6.5: *Population density in India*
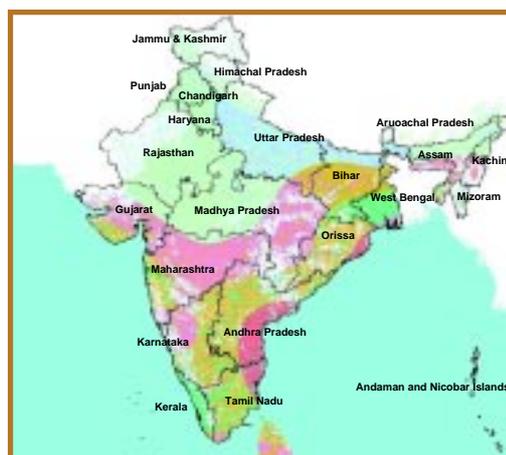
Figure 6.6: *Vulnerable population exposed to storm risk in India*

6.5   Results of the study

The GIS based analysis shows that more than half billion people are potentially affected by tropical storms in India. The following table illustrates that 20 states are affected by the tropical cyclone among 32 states and union territories (UT) in India. The table shows the vulnerable population in different states in India living in different storm risk zone.

Table 6.2 – List of vulnerable people affected by cyclone in different states and UTs of India

Name of the and UT	Per capita income of the state (Rs), 1996-97	% of total population	Vulnerable population in the storm riskState			
			1	2	3	4
Andaman and Nicobar Islands	12 653	0.03	-	568	78 617	237 656
Andhra Pradesh	10 590	7.91	-	6 945 353	44 798 612	25 421 168
Arunachal Pradesh	13 424	0.10	990 125	-	-	-
Assam	7 335	2.66	22 016 898	3 771 457	191 885	-
Bihar	4 654	10.29	24 212 092	63 566 239	12 599 841	-
Chandigarh	-	0.07	725 329	-	-	-
Dadra and Nagar Haveli	-	0.02	-	107 844	52 420	
Daman & Diu	-	0.01	-	94 019	31 481	-
Delhi	22 687	1.09	10 659 296	-	-	-
Goa	23 482	0.14		1 355 597	-	-
Gujarat	16 251	4.91	11 306 950	27 787 558	8 779 782	-
Haryana	17 626	2.00	19 467 310	-	-	-
Himachal Pradesh	7 355	0.61	5 919 175	-	-	-
Jammu & Kashmir	6 658	0.71	6 932 431	-	-	-
Karnataka	11 693	5.36	-	15 482 877	36 763 203	-
Kerala	11 936	3.46	-	3 141 365	30 566 568	-
Lakshadweep	-	0.00	-	11 511	25 580	-
Madhya Pradesh	8 114	7.89	49 812 172	25 054 153	2 091 106	-
Maharashtra	18 365	9.39	4 065 310	69 488 861	18 050 222	-
Manipur	8 194	0.22	-	2 118 531	7 040	-
Meghalaya	8 474	0.21	362 144	1 714 280	-	-
Mizoram	13 360	08	-	13 631	779 805	7
Nagaland	11 174	0.14	970 138	423 483	-	-
Orissa	6 767	3.77	-	3 202 679	28 635 942	4 934 940
Pondicherry	11 677	0.09	-	-	18 463	859 034
Punjab	19 500	1.95	18 980 768	-	-	-
Rajasthan	9 356	5.24	51 120 072	-	-	-
Sikkim	7 416	0.05	466 761	-	-	-
Tamil Nadu	12 989		-	2 918 748	46 145 579	15 823 653
Tripura	5 569	0.33	-	26 720	3 168 470	-
Uttar Pradesh	7 263	16.54	147 750 382	13 572 370	-	-
West Bengal	10 636	8.09	12 726 756	13 412 395	45 313 980	7 503 504
Total population in different risk zone	-	-	388 484 109	25 420 239	278 098 596	5 477 996
Total 32 states						**975 572 906**

Source: per capita income – *http://www.mapsofindia.com/maps/india/percapitaincome.htm*,,   Storm risk 1 represents low vulnerability and 4 represents high vulnerability

State level vulnerable people at risk are calculated for each risk zone. An estimated 54 million people are extremely vulnerable to cyclone who live in the high risk region (Storm risk zone 4), Approximately 278 million people live in moderately high vulnerable region (Storm risk zone 3). Approximately 254 million people live in the moderately vulnerable region (Storm risk zone 2) and rest of the population live in the low risk zone one, where they are only affected by light storms.

Low vulnerable areas (cyclonic risk 1)
An estimated 38 per cent of people live in the low risk cyclonic zone. Arunachal Pradesh, Himachal Pradesh, Chandigarh, Delhi, Haryana, Jammu and Kashmir, Punjab, Rajasthan, Sikkim are in the less vulnerable zone.

Moderate vulnerable areas (cyclonic risk 2)
An estimated 27 per cent of people live in the moderate vulnerable cyclonic zone. The most vulnerable are in Maharastra, Bihar, Maddha Pradesh and Gujarat.

Moderate high vulnerable areas (cyclonic risk 3)
An estimated 29 per cent of people live in the moderate-high vulnerable cyclonic zone. The most vulnerable are in Tamil Nadu, West Bengal, Andra Pradesh, Karnataka, Kerala and Orissa.

Highly vulnerable areas (cyclonic risk 4)
An estimated 6 per cent of people in India are highly vulnerable to cyclonic hazard. The most vulnerable, approximately 53 million, are in Andhra Pradesh, Orissa, Tamil Nadu and West Bengal.
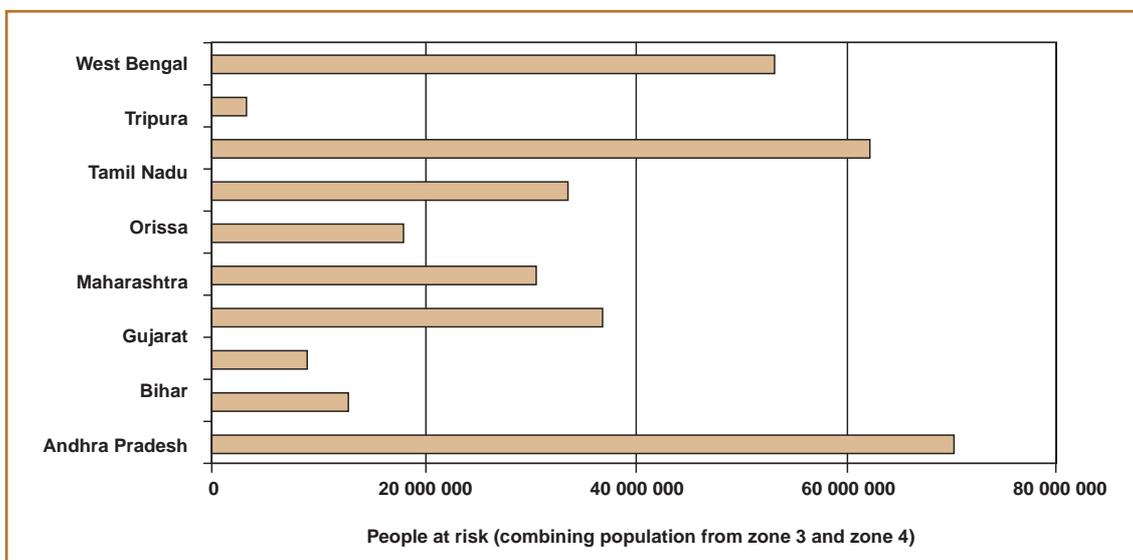
Figure 6.7: *High risk states in India*

6.6   Vulnerability and Coping Capacity

Coping means ability to withstand risks at a particular point of time. Coping could be money, deployment of technology, infrastructure or emergency response system. Coping is also the manner in which people act within existing resources and range of expectations of a situation to achieve various ends. This means how people are able to respond in unusual, abnormal, and adverse situations. Here per capita income of each states are used as the coping capacity of the states. As

raster (1 sq km pixel) data sets are not available for per capita income, State level data (www.mapsoftindia.com) is used for this analysis. The following map shows the coping capacity of different Indian states.

The state level map (Fig. 6.8) illustrates that Bihar, Tripura and Orissa are the poorest states based on their per capita income where Madhya Pradesh and Gujarat have high per capita income.

The results from combining storm risk and poverty map show that Orissa is the most vulnerable due to its low coping capacity (per capita 6 767 Rupees (47.03 rupees=1USD) and of cyclonic vulnerability. Tamil Nadu, Andhra Pradesh and West Bengal are also vulnerable because they lie in the vulnerable

Figure 6.8: Per capita income of different states in India. Dark red areas show low per capita income and dark yellow areas show high per capita income.

region and they have low per capita income as well. Maharashtra and Goa are two states also affected by cyclone risk but are less vulnerable to cyclones because of good coping capacity (per capita more than 18 365 Rupees). This analysis shows that in poor states, people become more vulnerable due to poverty (low per capita) and cyclonic risk.

This study reveals that vulnerability not only depends upon the exposure to hazard but also on coping capacity of the people. The study demonstrated that poor coping capacity (per capita) of the people is the underlying cause of this vulnerability. Coping capacity of the people is generally recognized as one of the most important correlates to reduce vulnerability to hazard. Building both the social and financial capital for the poor could be the best way to increase coping capacity of the nation and reduce vulnerability.

In summary, GIS tools can help to identify and locate populations vulnerable to a single hazard component. They have been used to calculate state-level populations in India affected by different types of storms and are the only tools available for calculating vulnerable population in the geospatial domain. Calculating vulnerability to multiple hazards by GIS remains a challenge for decision-makers.

Part 7: Conclusions and Discussion

The main conclusions of this study are:

- Vulnerability is a complex phenomenon. There are various concepts of vulnerability in the context of different dimensions: social, economic, environmental, food security, natural hazards and climatic change impacts.
- There are number of approaches to quantifying vulnerability to environmental changes. A number of attempts have been made to assess vulnerability using statistical tools, GIS-based mapping tools, modelling tools and composite indices.
- Vulnerability depends not only on exposure to hazard but also on the coping capacity of those exposed. The study has demonstrated that while Bangladesh is three times less vulnerable than the United States in terms of exposure to hazard, the number of deaths due to natural disasters in Bangladesh is 34 times higher. The underlying cause of this is the poor coping capacity of the people. Improving coping capacity is generally recognised as one of the most important ways of reducing vulnerability. This can best be achieved by building the social and financial capital of the poor.
- A Geographic Information System (GIS) based study showed that more than five hundred million people are vulnerable to cyclonic hazard in India. This approach can be used effectively to identify the geographic locations of vulnerable populations exposed to various hazards. It can also help to model climatic hazards and calculate the populations affected by extreme events and environmental changes.
- A composite index could be developed to show the relative status of human vulnerability to environmental changes. Such an index could help to provide a quick picture of environmental vulnerability on a global scale in a holistic, multidisciplinary way, enabling decision-makers to compare the relative overall human vulnerability due to environmental changes in different countries. But construction of such a composite index for vulnerability assessment is a challenging task. Further research is needed to develop an appropriate methodology and data collection for such an index.

Vulnerability includes risks to people, land, and infrastructure — but political and economic systems and other institutional arrangements are just as important as the environment. No standard framework exists for identifying the many intricate sources of vulnerability. Poverty is generally recognised as one

of the most important correlates of vulnerability to hazard, but it is neither necessary nor sufficient for it. The very young and the old are often identified as especially vulnerable. Other variables widely invoked are difference in health, gender, ethnicity, education, and experience with the hazard in question. Empirical, local-level studies reveal such complex mosaics of vulnerability as to cast doubt on attempts to describe patterns and establish trends at the global or even the regional scale.

Most of the vulnerability assessment literature does not include consideration of 'inability to cope' as a relevant policy factor. What is so interesting and potentially valuable about a vulnerability assessment is that it becomes a tool for thinking about the need to understand how the burdens of environmental degradation are distributed unequally around the globe. It is important to assess how different threats may be more or less catastrophic depending upon the community's ability to cope.

An example might be vector-borne disease: In the 'rich' countries, governments would respond with an expensive mosquito monitoring programme such as has been the case with the recent West Nile fever in the United States. However, such a response would not be affordable in many parts of the world. More examples of why 'ability to cope' is such an important policy consideration could help make the case for the importance of 'vulnerability' as a relevant policy consideration.

There is some danger in aggregating risks from various threats. Any vulnerability calculation involves numerous assumptions about things such as exposure opportunity and quantitative risk caused by the exposure, so any calculation will necessarily include value assumptions that are inevitable when making decisions in the face of scientific uncertainty. Such assumptions are unavoidable because an assessor must decide how conservative to be in the face of uncertainty. For instance, in the case of climate change, does the assessor assume that the risk posed by sea-level rise will be the middle-level projection or the upper quartile? Does the assessor consider such things as climate surprises, which could raise sea levels very rapidly from sudden Antarctic ice sheet melting, even if the probability of such an event is low? What about speculative but plausible impacts? Because risk assessment for any one problem must necessarily make numerous assumptions, it might be better not to aggregate risks from different threats but to talk about vulnerability from discrete threats and identify all value assumptions. If risks from different threats are aggregated, the numerical precision of a final calculation will suggest a false precision that will hide controversial value assumptions. A disaggregated approach would mean that rather than vulnerability from climate change being calculated as one number, there would be separate calculations for sea-level rise, storm damage, vector-borne disease, diminished food growing ability, etc. Each calculation would require identification of the data on which it was based and a clear articulation of how issues of scientific uncertainty were resolved.

Calculations of vulnerability at the national scale may show comparatively low vulnerability levels despite there being some highly vulnerable sub-populations or individuals in that nation. For example, although Canada may be less vulnerable to climate change from vector-borne disease than other nations because of high ability of the medical system to respond, those without medical insurance who live in areas where there are new threats from mosquitoes may be particularly vulnerable. A vulnerability calculation must decide how to deal with vulnerable populations that exist at smaller scales than that chosen for analysis.

In general, the factors that govern vulnerability are:

- the probability that an adverse event will occur;
- the probability distribution of the total costs if it does occur;
- the distribution of coping capacity.

Together these three elements define a 'vulnerability profile'. Its distribution can be narrow or broad. In a narrow distribution, the possible outcomes are not too dissimilar from one another, in a broad distribution, the range of possible outcomes is extensive. A fourth element is the robustness of the assessment of these probability distributions.

Changes in the probability distribution of the total costs are possible either by changing the probability that the adverse event will occur or by changing the total losses if it does occur. In addition, one could also invest in changing the distribution of allocation of responsibility for the costs or shift the contingent costs to other parties (e.g. insurance).

Traditionally, vulnerability, risk and early warning are applied in the context of environmental phenomena, primarily climatic (drought, floods, storms including hurricanes, typhoons, tornadoes) but also including geological, earthquakes, tsunamis, and volcanic eruptions that are in fact aperiodic. The term 'early warning' is itself often interpreted to mean 'prediction' when in fact the these episodic events, by their very nature, are not amenable to accurate long-term prediction in the strict sense. Early warning means just that, 'warning that an event is imminent, get out of the way!'

Early warning information can be produced in the context of a broader *vulnerability assessment process*, which includes the production of forecasts, but also communication of forecast information and the incorporation of that information into user decisions. The process might be thought of as a symphony orchestra in which the different sections must work together harmoniously to produce music (Drucker 1993). The analogue to music in the forecasting process is effective decision-making. The elements of such a process and the outcomes associated with each element are shown in Table 7.1 (Hooke and Pielke 2000).

Table 7.1 Elements of vulnerability assessments and their outcomes

Elements of vulnerability assessment	Outcome
Early warning	Forecast products
Communication	Guidance
Use	Decision

The key is to identify the users of early-warning information and the most efficient way to reach them with credible information to enhance their decision-making process.

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Appendix A   A summary of work on vulnerability indices

Title of the work and organisation	Key issues	List of indicators	Methodology used
The Index of Human Insecurity (IHI) The Global Environmental Change and Human Security (GECHS) Project Office University of Victoria, Canada http://www.gechs.org/researchreports.htm	IHI is a classification system that *distinguishes countries* based on how vulnerable or insecure they are, and groups together those countries that possess similar levels of insecurity. **Vulnerability mapping** Showing the regions of *Ecological Stress* and *Human Vulnerability*	Selected Indicators of Human insecurity comprising the standard set *Environment:* • Net energy imports (%of commercial energy use) • Soil degradation (tonnes/year) • Safe water (%of population with access) • Arable land (ha/person) *Economy* • Real GDP per capita (USD) • GNP per capita growth (annual %) • Adult literacy rate (%of population 15+) • Value of imports and exports of goods and services (%of GDP) *Society* • Urban population growth (annual %) • Young male population (% aged 0-14 of total population) • Maternal mortality ratio (per 1000 live births) • Life expectancy (yrs) *Institutions* • Public expenditures on defence versus education, primary and secondary (%of GDP) • Gross domestic fixed investment (%of GDP) • Degree of democratisation (on a scale of 1-7) • Human freedoms index (on a scale of 0-40)	In summary, the following steps were used to calculate the IHI. 1. A complete time series for all indicators and all countries was established. Data were collected, where available, for the years 1970 through 1995. As most countries did not have complete time series for most indicators, it was desirable to estimate missing time series data through some relatively simple statistical techniques (**linear regression or data interpolation**) where the existing data was sufficient; 2. The data were **standardised**. Indicators were adjusted so that they use the same unitless scale and possess the same range of possible values, so that all indicators are given the same weight in the composite index; 3. The data were **classified** and the index calculated. Data for each indicator were classified for each year into **10** categories by **cluster analysis.** Countries were assigned a number between 1 and 10 for each indicator for which they had a known or estimated value. The corresponding IHI value was then calculated for each country in each year as the average category value for all indicators.[1]
The Global Environmental Change and Human Security Report 1		**Vulnerability mapping Indicator** **12** indicators were selected among **6** categories: • Ecological/Resource Indicators • Economic Indicators • Health Indicators • Social and Demographic Indicators • Political/Social Indicators • Food Security Indicators The indicators which comprise the "Index of Vulnerability" are: 1. Food Import Dependency Ratio 2. Water Scarcity 3. Energy Imports as a Percentage of Consumption 4. Access to Safe Water 5. Expenditures on Defence vs. Health and Education	**Vulnerability mapping method** All data were stored and mapped using GIS software packages ArcInfo and ArcView. The raw data were converted to relative scores by performing a **hierarchical cluster analysis**. This statistical procedure groups like-data in **10** different clusters. The procedure is used to ensure consistency across indicators (in terms of

[1]   Lonergan,S. 1998, *The Role of Environmental Degradation in Population Displacement,* Global Environmental Change and Human Security Project, Research report 1, University of Victoria, Victoria, B.C. Available http://www.gechs.org/researchreports.htm

		6. Indicator of Human Freedoms 7. Urban Population Growth 8. Child Mortality 9. Maternal Mortality 10. Income per capita 11. Degree of Democratisation 12. Fertility Rates	combining data with different units) and to separate dissimilar data, particularly at the extremes. Under this analysis, there is no set number of data points which are assigned to each cluster; in some cases there may be only one country assigned to a cluster. The cluster analysis was used to generate **standardised scores**, ranging from **1 - 10**, which would subsequently make up the individual components of the vulnerability index. The 10 clusters were then **aggregated** to **5**, and each of the 12 indicators were then mapped.
Vulnerability analysis and Mapping (VAM) World Food Programme http://www.wfp.it/ docsearch/general.asp	Vulnerability mapping guidelines for food insecurity. Locate the geographic area where people are vulnerable.	Suitable indicators of vulnerability to food insecurity vary enormously between countries. WFP *did not provide* an exhaustive list of potential indicators *Two categories* of indicator were found: a. indicator of "risk of an event" b. indicators of "coping ability" a. Risk of event indicators are those which provide information on: -the likelihood of a shock or disaster event that will adversely affect food security, e.g. drought; -the likely severity and impact of that event. b. Coping ability indicators are those which provide information on: -the capacity of populations affected by an event to withstand its effects. **Selected Indicators: Data** sets constructed from information on socio-economic variables (Quantitative & Qualitative data) - food aid deliveries - agricultural land use - rainfall estimates- vegetation index data- soil moisture content - market and price movements - basic infrastructure and logistical data for preparedness and response purposes *Develop a geo-referenced database to cover*: Sources of *risk* (types of food security problems, shocks and disaster events, including severity and frequency, agro-economic factors, flood and drought-prone areas, refugee-affected areas,	*Approaches to the Mapping of Food-Related Vulnerability* A number of different approaches are available or have been employed for mapping food-related vulnerability, each of which has particular strengths and weaknesses. **Five** are identified here. In practice sometimes two or more of these approaches are combined. - Disaggregating existing data on socio-economic Groups - Undertaking new statistical surveys to collect data directly relevant to vulnerability - Using existing data as key indicators of vulnerability - Rapid rural appraisal methods - Delbecq-Delphi Methods This approach was followed by existing data analysis and effective use of **GIS** technology **Vulnerability Mapping** Preparation of **separate maps** of each of the selected data-based indicators; **weight** and **overlay** the data-based maps to build up a **map of aggregate vulnerability**. Prepare subjective, experience-based maps for comparison and to complement data-based maps where quality or coverage of data is poor. **Weight** the composite, data-based map and the aggregate, subjective, experience-based map to produce a **composite map** of vulnerability

		food prices, etc.). *Socio-economic* data, disaggregated by gender where possible or appropriate. Entitlements and coping mechanisms (income sources, distribution and levels of indebtedness both spatially and by social class, food stocks, household assets, infrastructure and service provision, health and nutritional status, claims on government or community support systems, relief aid distribution)	**Creation of composite maps** 1) Analysis of vegetation data 2) Identifying likely areas of crop losses 3) Food availability data base and maps from district level production data 4) Mapping livestock data 5) Price data mapping 6) Identifying flood risk areas 7) Market access maps 8) Health access maps 9) Composite map for analysis
FEWS Vulnerability Assessment Famine Early Warning System (FEWS) by **USAID** www.fews.org *FEWS Vulnerability Assessment* Famine Early Warning System (FEWS) by **USAID**	Baseline Vulnerability Analysis The outcome is a classification of populations living in different areas by degree of food insecurity - a first screening for targeting assistance, including food aid Project Area **Sub-Saharan Africa**	FEWS classifies populations in to **4** categories -**food secure** or **moderately, highly,** or **extremely food insecure** Geographic and Demographic data collected.	**Measuring food access-** Aggregate current income is calculated in per-capita terms for the lowest administrative level for which reliable secondary data are available. Sources of measured income can include food crops, cash crops, livestock, fishing, artisanal products, wage employment, remittances and food aid. This sum of measured income is compared to a desired consumption-based income threshold. If current measured income lies above the threshold, the areas are considered food secure. **Index Construction[2]** Indices may be constructed in five basic steps: (1) determination of the primary 'dimensions' of vulnerability for which indices will be constructed; (2) selection of indicators to be used in each index; (3) standardisation of indicators; (4) weighting of indicators within indices; (5) ranking according to summed scores. Methodology in detail **Standardisation:** It is difficult to compare measures of rainfall and soils, for example. Thus, indicators are transformed into some common measure. This may take the form of numeric ranking (from best to worst), scaling (as a percentage of

[2] World Food Programme(WFP) 1999, *Vulnerability Analysis and Mapping (VAM).* Available USAID 1999, *Introduction to Current Vulnerability Guidelines,* FEWS Current Vulnerability Assessment Guidance Manual, Available http://www.info.usaid.gov/fews/va/cvaguide/cvaguidehome.html

maximum value), or transformation or scaling (e.g., z-scores). It has also taken the form of transforming indicators into a common denominator (e.g., food or monetary equivalents), but this is not necessarily the required endpoint. Scaling or other data transformations can be done for time-series data for each area (temporal), or over many areas for data representing one point in time (spatial). Each approach offers advantages and disadvantages.

Weighting: Indicators are assigned weights according to their relative importance. Using no (equal) weights assumes that all indicators are of equal importance. However, it is usually clear that some variables are more important than others and this difference must be accommodated during analysis. In the past, weights have been developed through the best judgement of the analyst, through experience, or through the use of expert opinion.

Ranking: After indicators have been standardised and weighted, they can be summed to create the dimension index. Subsequently, areas can be ranked according to these sums. At times, the indices themselves are weighted and summed to create an overall vulnerability index so that areas can be ranked. This may be done, but it should be as transparent as possible, so that its meaning to the decision-maker is clear.

Understanding Urban Seismic Risk Around The World: Evaluation and use of the **Earthquake disaster Risk Index (EDRI)** **Risk Assessment Tools for Diagnosis of Urban Areas against Seismic Disasters (RADIUS) Project**	Developed a *composite index* that was developed to facilitate *worldwide inter-city comparison* of the magnitude and nature of urban earthquake disaster risk. EDRI results are illustrated using the results of a ten-city sample analysis which allows direct comparison of the relative overall	***The index is calculated based on 31 indicators covering 5 main factors components.*** *Hazard* Ground shaking • Exp (MMI w/50 year return period) • Exp (MMI w/500 year return period) • %of urbanised area w/soft soil Collateral Hazard • %of urbanised area with high liquefaction on susceptibility • % of buildings that are wood • population density • Tsunami potential indicator	The EDRI was developed using a **three-step** procedure. 1. a conceptual framework was created to represent all the **factors -** geological, engineering, social, economic, political, and cultural - that contribute to a city's earthquake disaster risk. A contributing factor was considered to be any characteristic of a city's physical makeup, location, residents, or

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http://www.geohaz.org/radius/ An initiative for **IDNDR The** IDNDR Secretariat Office for the Coordination of Humanitarian Affairs United Nations	earthquake disaster risk and describes therelative contributions of various factors (e.g. hazard, exposure, vulnerability) to that risk.	*Exposure* Physical infrastructure exposure • Population • Per-capita GDP • Number of housing units • Urbanized land area Population exposure • Population Economy exposure • Per-capita GDP Vulnerability Physical infrastructure vulnerability • Seismic code indicator • City wealth indicator • City age indicator • Population density • City development speed indicator Population vulnerability • % of population aged 0-4 or 65+ *External context* Economic external context • Economic context indicator Political external context • Political country context indicator • Political world context indicator *Emergency response and Recovery Planning* Planning • Planning indicator Resources • Per-capita GDP • 10 y av. of annual real growth in per-capita GDP • housing vacancy rate • no. of hospitals per 100,000 people • no. of doctors per 100,000 people Mobility and access • Extreme weather indicator • Population density City layout indicator	activities that can significantly affect the expected impact from earthquakes. 2. one or more simple, scalar, measurable indicators (e.g., population, per-capita GDP, percentage of the urbanised area that is soft soil) were selected to represent each of the broad, abstract factors in the framework. 3. A mathematical model was developed to combine the indicators into the composite EDRI that best represents the concept of earthquake disaster risk.[3] EDRI combines the 31 indicators and develop a **composite index** with three steps: (1) scaling; (2) weighting; (3) combining.
Environmental Vulnerability Index (EVI) South Pacific Applied Geosciences Commission **(SOPAC)** ***Environmental Vulnerability Index (EVI)*** *SOPAC*	The focus of SOPAC is on the vulnerability of the environment to both *human* and *natural hazards* An important step towards the development of *composite vulnerability index* encompassing both economic and environmental vulnerability.	The SOPAC identifies ***three aspects*** of environmental vulnerability: 1. level of risks (or pressures) on the environment; 2. resilience of the environment to pressures, or intrinsic vulnerability; 3. the level of degradation of ecosystems, or extrinsic resilience. For each of these aspects a sub-index was calculated; the *three sub-indices* were then averaged to construct the overall index. A total of **47** indicators were used:	*Methodology for Indexing:* The data were collected for five countries (Fiji, Samoa, Tuvalu, Vanuatu and Australia) for initial testing. All variables were normalised on a scale from 1 to 7. The three sub-indices were then constructed as weighted averages of the relevant indicators. Then the sub-indices were renormalised and averaged to form the overall index. Three experimental weighting schemes were used:

[3] Davidson, R. A and Haresh C. Shah 1998, *Understanding Urban Seismic Risk Around The World: Evaluation and use of theEarthquake disaster risk index,* Risk Assessment Tools for Diagnosis of Urban Areas against Seismic Disasters (RADIUS) project. Available http://www.geohaz.org/radius/Doc_B.html
SOPAC Technical Report 306: Ursula Kaly, and Craig Pratt, *Environmental vulnerability index: Development and provisional indices and profiles for Fiji, Samoa, Tuvalu, and Vanuatu* (February 2000).

| | | 26 indicators of risk, 7 indicators of resilience, and 14 indicators of environmental degradation. The indicators are also classified by scientific categories; meteorological, geological, biological, anthropogenic, and intrinsic county characteristics . | (a) equal weighting; (b) weights of 1, 2 and 3 reflecting judgement as to low, medium or high importance; (c) stronger differentiation with weights of 1, 5, and 10 reflecting relative importance. |

List of indicators in sub-index
Risk Exposure sub-index REI(26)
1. Sea surface temperature
2. High winds
3. Dry periods
4. Wet periods
5. Heat waves
6. Cold snaps
7. Volcanic eruptions
8. Earthquakes
9. Tsunamis
10. Potential for introductions 11. Pathogens and plagues
12. Human population density
13. Human population growth rate
14. Rate of loss of natural vegetation
15. Tourists
16. Wastewater
17. Production of hazardous and municipal wastes
18. Waste treatment
19. Oil spills
20. Toxic industries
21. Vehicles
22. SO_2 concentration
23. Fertilisers
24. Pesticides
25. Fisheries stocks
26. Sub surface mining

Intrinsic Resilience sub-index IRI (7)
Land area
Fragmentation or "islandness"
Isolation
Vertical relief
Lowlands
Coastal vulnerability
Endemic species

Environmental degradation sub-index EDI (14)
1. Introductions
2. Endangered species
3. Extinction
4. Natural vegetation
5. Intensive farming
6. Fisheries
7. Coastal settlements
8. Degradation
9. Water resources
10. Surface mining
11. Terrestrial reservoirs
12. Marine reservoirs
13. War/civil strife
14. Legislation

When data for some indicators were not available, averages were constructed excluding those indicators. For this approach to provide a reasonable measure of vulnerability, the authors suggest that data for at least 80 per cent of the indicators be collected. Work is underway to extend the phase II study to an additional thirteen countries around the world.[1]

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[1]   For further information, see Commonwealth Secretariat, Economic Paper 40: Jonathan A. Atkins, Sonia Mazzi, and Christopher D. Easter*, A Commonwealth vulnerability index for developing countries: the position of small states,* Annex IV "Environmental index for developing and island states."

Pilot Environmental Sustainability Index.
 	
An initiative of the Global Leaders for Tomorrow Environment Task Force, **World Economic Forum**
 	
Yale Center for Environmental Law and Policy (YCELP) of Yale University and Center for International Earth Science Information Network (CIESIN) of Columbia University, www.weforum.org/pdf/glt/glt_esi_2000.pdf
	Environmental Sustainability Index	This index was calculated for 56 economies, of which 25 are developing countries and 31 are developed countries or countries with economies in transition, utilising 64 individual variables covering 21 factors and 5 components regarded by the authors as fundamental for environmental sustainability. These components and factors are
		(a) environmental systems health:
		  1. Urban air quality
		  2. Water quantity
		  3. Water quality
		  4. Biodiversity
		  5. Land
		(b) environmental stresses and risks:
		  1. Air pollution
		  2. Water pollution and consumption
		  3. Ecosystem stress
		  4. Waste production and consumption pressure
		  5. Population
		(c) human vulnerability to environmental impacts:
		  1. Basic sustenance
		  2. Public health
		  3. Disasters exposure
		(d) social and institutional capacity:
		  1. Science and technical capacity
		  2. Capacity for rigorous policy debate
		  3. Environmental regulation and management
		  4. Tracking environmental conditions
		  5. Eco-efficiency
		  6. Public choice failures
		(e) global stewardship:
		  1. Contribution to international cooperation
		  2. Impact on global commons
			The 64 variables were **normalised** to a scale of 0 to 100 and then assigned **equal weights** to construct **twenty-one composite factors**. These composite factors were in turn assigned equal weights in constructing the **composite** environmental sustainability index and, composite indices for each of the five fundamental components. This approach assigns equal weights to the twenty-one factors rather than to the five components in constructing the composite environmental sustainability index. An advantage of this approach is that the problem of missing variables can be partially addressed by assigning equal weights to those variables which <u>are</u> available for each factor.
			VARIABLES (64)
			
			FACTORS (21)
			
			COMPONENTS (5)
			
			ENVIRONMENTAL SUSTAINABILITY INDEX

The Commonwealth vulnerability index for developing countries The Commonwealth Secretariat	Developed an environmental index meant to be applicable to developing countries and Island states Project area 111 countries	Applicable to developing and island states and has compiled two variants for 111 countries. **Six indicators** were selected to reflect pressure on the natural environment: 1. Annual rate of deforestation 1980-1990 2. Population density 3. Annual water use as a percentage of total water resources 1980-1990 4. Ratio of coastline to land area 5. Ratio of threatened species to land area	*Methodology for indexing* Each of these indicators was normalised and assigned equal weight to form the **composite index.** Because of numerous gaps in coverage for the indicator of water use, one index is calculated with water use included and another with it excluded.[2]

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[2] For further details, see Committee for Development Policy, Report on the second session (2000) Economic and Social Council Official Records, 2000 Supplement No. 13.

		6. Ratio of total number of natural disasters to land area, 1970-1996.	
Economic vulnerability index (EVI) The Committee for Development Policy (CDP)	*Economic vulnerability index (EVI)* covering *128 developing countries* for use in identifying the *least developed* among the developing countries.	The CDP EVI identifies **three aspects** of vulnerability: 1. size and structure of the economy 2. exposure to international trade shocks 3. exposure to natural disasters. Five variables are used to capture these three aspects: 1. population size 2. share of manufacturing and modern services in GDP 3. export concentration 4. export instability 5. instability of agricultural production.	These five variables are **normalised** and **averaged** with **equal weights** to construct the **composite index.** The ranking of the 128 developing countries is displayed in Annex 1.[3]
Economic vulnerability index (EVI) The Caribbean Development Bank (CDB)	The Caribbean Development Bank (CDB) has developed another *Economic vulnerability index (EVI)* covering *95 countries* as a *measure of the development challenge* facing Caribbean developing countries.	The CDB EVI identifies *five factors* which contribute to economic vulnerability: 1. peripherality and energy dependence 2. export concentration 3. convergence of export destination 4. reliance upon external finance 5. susceptibility to natural disasters. These five factors are measured using eleven variables: 1. freight and insurance costs as a percentage of imports CIF 2. net energy imports as a percentage of total energy consumption 3. the proportion of total exports represented by the top single export category 4. the proportion of total exports represented by the top three export categories 5. total export receipts as a percentage of GDP 6. the proportion of total exports to the top single export destination 7. the proportion of total exports to the top three export destinations 8. the ratio of official development assistance disbursement to gross fixed capital formation	These 11 (eleven) variables are **combined** in various ways to calculate values for the five factors. These, in turn, are **normalised** and combined with **equal weights** to form the **composite index.**[4]

[3] For further details, see Caribbean Development Bank Staff Working Paper No 1/00: Tom Crowards, *Comparative Vulnerability to Natural Disasters in the Caribbean* (May 2000) and Caribbean Development Bank Staff Working Paper (forthcoming): Tom Crowards, *An index of economic vulnerability for developing countries* (February 2000). Footnotes to these papers note that the views expressed are those of the author and do not necessarily represent those of the Caribbean Development Bank.

[4] For further details see Commonwealth Secretariat, Economic Paper 40: Jonathan Patkins, Sonia Mazzi and Christopher D. Easter, *A Commonwealth vulnerability index for developing countries: The position of small states* (January 2000).

		9. the ratio of annual foreign direct investment to gross fixed capital formation 10. the number of people "affected" by natural disasters, 1950-1998, as a proportion of total population.	
Economic vulnerability index (EVI) The Commonwealth Secretariat	Developed an *Economic Vulnerability Index (EVI)* designed to *quantify the vulnerability* of countries and hence provide a means to identify particularly vulnerable countries. Such an index could serve as *an operational tool* in determining whether *small states* should be accorded *differential treatment* by the international development community.	EVI identifies income volatility and resilience as the **two key dimensions** of vulnerability. Income volatility is measured by a vulnerability impact score which is calculated by combining **three variables:** 1. Average exports of goods and non-factor services as a percentage of GDP 2. the UNCTAD index of merchandise export diversification 3. the number of people 'affected' by natural disasters as a proportion of total population 1970-1996.	A vulnerability impact index is constructed using **weights** derived from **regression analysis**. A resilience index is derived from *gross domestic product.* The vulnerability impact index and the resilience index are then **combined** to form the Commonwealth vulnerability index using weights derived from **principal components analysis**.[5]
Institute of Advanced Studies (UNU/IAS) **United Nations University**	Developed a *Geographic Vulnerability Index (GVI)* covering *100 developing countries* as a possible extension of other economic vulnerability approaches. Its main purpose is to measure *geographic vulnerability,* with special reference to *Small Island Developing States* (SIDs).	The GVI identifies **four dimensions** of geographic vulnerability: 1. insularity 2. peripherality 3. population concentration 4. susceptibility to natural disasters. These four dimensions are measured by **four variables**: 1. length of shoreline divided by land area 2. freight and insurance costs as a percentage of imports CIF 3. proportion of population living in urban areas 4. number of people 'affected' by natural disasters as a proportion of total population, 1970-1996.	These four variables are **normalised** and assigned **equal weights** to form the composite Geographic Vulnerability Index.[6]

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[5] For further details, see United Nations University Institute of Advanced Studies, UNU/IAS Working Paper (forthcoming); Rosario Adapon Turvey, *Methodology for vulnerability assessment of developing countries with relevance to small islands and least developed countries* (March 2000).

Appendix B

Abbreviations

CRED	Centre for Research on the Epidemiology of Disasters
DEWA	Division of Early Warning and Assessment
DMSP	Defense Meteorological Satellite Program
EROS	Earth Resources Observation Systems
ESRI	Environmental System Research Institute
FAO	Food and Agriculture Organization
GCRIO	Global Change Research Information Office
GECHS	Global Environmental Change and Human Security
GEO	Global Environment Outlook
GIS	Geographic Information System
GRID	Global Resource Information Database
IPCC	Intergovernmental Panel on Climatic Change
IDNDR	International Decade for Natural Disaster Reduction
LAW	Land, Air, Water
LDC	Less Developed Countries
NOAA	National Oceanic and Atmospheric Administration
OECD	Organization for Economic Cooperation and Development
PREVIEW	Project for Risk Evaluation, Information and Early Warning
RADIUS	Risk Assessment Tools for Diagnosis of Urban Areas against Seismic Disasters
SIDS	Small Island Developing States
SOPEC	South Pacific Applied Geoscience Commission
UNHCR	United Nations High Commissioner for Refugees
USGS	United States Geological Survey
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UT	Union Territories
WHO	World Health Organization
WB	World Bank
WRI	World Resource Institute
WFP	World Food Programme

Appendix C

Glossary of terms

Disaster

Situation or event, which overwhelms local capacity, necessitating a request to national or international level for external assistance (definition considered in EM-DAT); An unforeseen and often sudden event that causes great damage, destruction and human suffering. Though often caused by nature, disasters can have human origins. Wars and civil disturbances that destroy homelands and displace people are included among the causes of disasters. Other causes can be: building collapse, blizzard, drought, epidemic, earthquake, explosion, fire, flood, hazardous material or transportation incident (such as a chemical spill), hurricane, nuclear incident, tornado, or volcano (Disaster Relief).

Early Warning

is a notice/condition that alerts the public by forecasting an impending phenomenon or condition. Vulnerability assessment is one of the potential tools for generating early warning information.

Risk

The probability that an event will occur; a measure of the degree of loss expected by the occurrence of an event. (National Research Council 2001)

Susceptibility

Probability that an individual or population will be affected by an external hazard, such as infection by a pathogen. (National Research Council 2001)

Vulnerability

Extent to which a population is liable to be harmed by a hazard event. Depends on the population's exposure to the hazard and its capacity to adapt or otherwise mitigate adverse impacts (National Research Council 2001).