Chapter 4
CONCLUSIONS AND RECOMMENDATIONS

The aim of this Report is to map out an agenda for change in the way disaster risk is perceived within the development community. It presents a range of opportunities for moving development pathways towards meeting the MDGs by integrating disaster risk reduction into development planning.

The Report argues that disaster risk is a product of inappropriate development choices, just as much as it is a threat for future development gains.

This Chapter summarises key findings from the analysis of disaster risk and the discussion of disaster-development linkages undertaken in the Report.

The summary leads into six recommendations for further action. Each proposal is kept broad, drawing from the evidence presented in the preceding chapters. Each recommendation supports a specific agenda for reform in the management of development processes and disaster risk, which will need to be unpacked and further developed in each specific regional and national context.

At the beginning of Chapter 1, four questions concerning the disaster-development relationship were posed. The first two questions guided attention to the mapping of disaster risk and its relationship with development. By way of a summary, we return to them again in section 4.1. The final two questions sought ways for refining development policy and disaster risk assessment tools to enhance the practice of disaster risk reduction. These are addressed through the presentation of recommendations in section 4.2.

4.1 Development and Disaster Risk

4.1.1 How are disaster risks and human vulnerability to natural hazards distributed globally between countries?

The DRI exercise undertook the first global level assessment of natural disaster risk, calibrated according to the risk of death between 1980 and 2000.

Four natural hazard types (tropical cyclones, earthquakes, floods and droughts) responsible for 94 percent of the deaths triggered by natural disaster were examined. The population exposed and relative vulnerability of countries to each hazard were calculated. The drought DRI was presented as a work in progress at this stage.

Results are summarised below in global terms and for each hazard type. In global terms and for the four hazard types, disaster risk was found to be considerably lower in high-income countries than in medium- and low-income countries.

Earthquake
High relative vulnerability was found in countries such as the Islamic Republic of Iran, Afghanistan and India. Other medium-development countries with sizeable urban populations, such as Turkey and the Russian Federation, were also found to have high relative vulnerability. As well as countries such as Armenia and Guinea that had experienced an exceptional event in the reporting period.

Tropical cyclone
High relative vulnerability was found in Bangladesh, Honduras and Nicaragua, all of which had experienced a catastrophic disaster during the reporting period. Other countries with substantial populations located on coastal plains were found to be highly vulnerable, for example India, the Philippines and Viet Nam.

Flood
Flooding was recorded in more countries than any other hazard. High vulnerability was identified in a wide range of countries and is likely to be aggravated by global climate change. In Venezuela, high vulnerability was due to a single catastrophic event. Other countries with high vulnerability to floods included Somalia, Morocco and Yemen.

Drought
African states were indicated as having the highest vulnerability to drought. Methodological challenges prevent any firm country-specific findings from being presented for this hazard. The assessment strongly reinforced field study evidence that the translation of drought into famine is mediated by armed conflict, internal displacement, HIV/AIDS, poor governance and economic crisis.

For each hazard type, small countries and in particular, small island developing states, had consistently higher relative exposure to hazard. And in the case of tropical cyclones, this was translated into high relative vulnerability.

4.1.2 What are the development factors and underlying processes that configure disaster risks and what are the linkages between disaster risk and development?

The measurement of hazard-specific relative vulnerability for each country flagged the importance of mediating development processes in the translation of natural hazard into disaster risk.

In many countries, despite large exposed populations deaths were low (Cuba and Mauritius for tropical cyclones), suggesting development paths that contained disaster risk in various ways. For other countries, deaths were very high (Honduras and Nicaragua for tropical cyclones), indicating development paths that had led to the accumulation of catastrophic levels of disaster risk.

The analysis of socio-economic variables, available with international coverage, and recorded disaster impacts enabled some initial associations between specific development conditions and processes with disaster risk. This work was undertaken for earthquake, tropical cyclone and flood hazard. A lack of appropriate variables limited the confidence that could be placed on the analysis of drought. Consequently, no findings for this hazard are presented here.

Losses to earthquakes were associated with countries experiencing rapid urban growth and high physical exposure. For tropical cyclone, losses were associated with a high percentage of arable land and high physical exposure. Vulnerability factors associated with flood were low GDP per capita, low local density of population and high physical exposure.

Further analysis was structured around two development factors shaping contemporary disaster risk: rapid urbanisation and rural livelihoods.

Rapid urbanisation configures disaster risk through a range of factors: the founding of cities in hazard-prone locations, the concentration of population in hazard-prone locations, social exclusion and poverty, the complex interaction of hazard patterns,the generation of physical vulnerability, placing cultural assets at risk, the spatial transformation of new territories, and access to loss mitigation mechanisms.

In general, disaster risk considerations are rarely factored into urban and regional planning and the regulation of urban growth has been ineffective in managing risk. Economic globalisation concentrates economic functions in cities that might be at risk and promotes the speedy flow of international capital — heightening inequality and instability, but also providing opportunities for building capacity and resilience.

In rural areas, livelihoods become at risk due a range of factors: poverty and asset depletion, environmental degradation, market pressures, isolation and remoteness, the weakness or lack of social services and climatic fluctuations and extremes. Global climate change makes rural livelihoods more risk-prone by increasing uncertainty.

The configuring of risk by contemporary patterns of urbanisation and rural livelihoods needs to be viewed alongside other critical development pressures. Violence and armed conflict displaces people and disrupts social and economic development. Changing epidemiologies, especially of HIV/AIDS, malaria and tuberculosis, bring new configurations of hazard. Changing governance regimes offers possibilities for the integration of international with national and local action to reduce disaster risk. The increased role played by civil society in development and disaster risk reduction highlights the capacity of local actors to organise and confront disaster risk.

The Report argues that meeting the MDGs will be made more difficult if disaster risk is not integrated into development planning. More positively, if the MDGs are met this could result in a substantial reduction of international disaster risk. Whether this is the case depends on the extent to which synergies in the disaster risk and development agendas are recognised and acted upon.

The next section advances recommendations for building a closer synthesis between disaster risk and development planning.

4.2 Recommendations

Recommendations 4.2.1 to 4.2.5 propose an agenda for change in broad terms. A final section,4.2.6,presents a more detailed set of recommendations to enhance the data collection and analysis of disaster risk that should underpin the process of integration. They emanate from the experience of undertaking the DRI.

4.2.1 Governance for risk management

Appropriate governance for disaster risk management is a fundamental requirement if risk considerations are to be factored into development planning,and if existing risks are to be successfully mitigated.

A number of key elements in governance regimes were highlighted in the Report.They deserve reiteration as critical areas for reform in building national and global disaster risk reduction capacity and in mainstreaming disaster risk management.

The detailed changes in elements of governance advocated here can be interpreted as an outcome of the influence of a particular body of rules and values, that place importance on equity in the distribution of risk, and security and widespread participation in decision-making. These are key tenets of UNDP's perspective on international development and inform the basic orientation of this Report.

There is a need for institutional systems and administrative arrangements that link public, private and civil society sectors and build vertical ties between local, district, national and global scale actors.

Legislative reform is necessary but on its own, not a sufficient tool for increasing equity and participation. Legislation can set standards and boundaries for action, for example, by defining building codes or training requirements and basic responsibilities for key actors in risk management. But legislation on its own cannot induce people to follow these rules. Monitoring and enforcement are needed.

Legislation has its strength in societies where most activities take place in the formal sector and are visible to administrative oversight. In many high-risk nations and locations, monitoring and enforcement — and even widespread knowledge — of legislation is not achievable in the short- to medium-term because of financial and human resource constraints.

Fortunately, the principles of equity and participation in disaster risk management are not solely dependent on legislative reform. Much of the discussion in Chapter 3 sets out key pathways through which good governance can be enacted beyond legislative standards. The strategies described outline ways in which inclusive decision-making could be encouraged so that the knowledge and views of all stakeholders in development and disaster risk management could become involved.

The key challenge in building governance structures for human development and risk reduction is to play off efficiency with equity. Decisions often have to be made quickly, but rapid decision-making can factor in participatory approaches if planned appropriately. Enhancing the influence of local actors, through their participation in the local governance of risk,offers great potential for increasing the sensitivity and responsiveness of development planning to disaster risk.

The ISDR/UNDP Framework to Guide and Monitor Disaster Risk Reduction has the potential to make risk governance more transparent. If taken up globally, international comparisons will help refine and target policies to reduce risk and build a structured approach to the identification of good practice.

4.2.2 Mainstreaming disaster risk into development planning

Development needs to be regulated in terms of its impact on disaster risk.

For many projects,especially large industrial developments, environmental and social impact assessment and risk assessment provide a ready framework for building disaster risk assessment into development planning. What is missing is a detailed procedure for identifying, categorising and placing some appropriate value on disaster risk. Again, the technical tool kit exists to build such a framework. In addition to quantitative environmental and social impact and risk assessments, and insurance risk assessment methods, more qualitative methods for judging investment risk could be applied. What is missing is the political will to build a more holistic assessment of development impact into development planning.

Assessing disaster risk will put the spotlight on environmental and social externalities, sometimes at temporal and spatial distance from specific developments. Making disaster risk reduction explicit in planning a development could enable a broad participatory decision-making process, in which levels of acceptable risk can be debated on a case-by-case basis. National and municipal governments will need to be lead actors in this process, perhaps aided by international actors.

Some examples of existing best practice can be pointed to. The World Bank, through its Disaster Management Facility, has begun to incorporate disaster risk into its lending considerations. Up to 1999, US$ 6.5 billion in loans included some form of mitigation to reduce disaster vulnerability within a larger development project.[1] Innovative urban planning for rapidly expanding cities has shown the need for flexibility in applying planning regulations, but also the great need to apply planning guidance quickly as cities grow. The aims are simple. For example, by keeping access roads and fire breaks between housing blocks to enhance security from urban environmental risk, fire and communicable disease. These tasks require a rethinking of the professional role of urban planners and the legitimacy of peri-urban satellite settlements, many of which might not have formal land rights. Creative thinking and political support are needed to move this agenda forward, but the seed is there.

Perhaps the greatest challenge with mainstreaming disaster risk into development planning is geographical equity. This is a problem shared with environmental management and environmental impact assessment. How to attribute responsibility for disaster risk experienced in one location, but created by actions in another location?

Examples of this dilemma include the degradation of fisher-people's livelihoods and health from the pollution of waters by urban sewerage or industrial practices, or the contributions of individuals and industrial production to global climate change.

Attributing responsibility is particularly problematic when degradation and risk is the consequence of multiple actions from multiple locations spread over time. This is an ongoing area of concern for the wider environmental management community with opportunities for cross-fertilisation in policy innovation.

The observation in this Report is that environmental impact assessment should be extended to include a risk analysis component.

Factoring risk into disaster recovery and reconstruction
The argument made for mainstreaming disaster risk management is doubly important during reconstruction after disaster events.

It has long been argued that reconstruction efforts need to learn from the disaster experience and factor risk-reduction strategies into the rebuilding of the physical and social fabric after a disaster. Unfortunately, there are still many examples where reconstruction means the rebuilding of pre-disaster risk or perhaps worse — an incomplete effort that leaves many without the basic necessities for maintaining a livelihood or their physical or psychological health. With more than thirty years of international experience in disaster reconstruction, many examples of good practice are available but need to be more widely applied.

And further work is required. Tools need to become mainstreamed within disaster reconstruction programmes as well as ongoing development. Reconstruction is often a politically opportune moment to introduce change into development procedures or goals. It can offer a more easily justified moment to introduce disaster risk at the programme and project levels.

4.2.3 Integrated climate risk management

Building on capacities that deal with existing disaster risk is an effective way to generate capacity to deal with future climate change risk.

Over the long-term, climate change will manifest as a difference in baseline weather parameters. But more importantly, this change is likely to be experienced as an increase in both the frequency and magnitude of extreme hydrometeorological hazards, such as tropical cyclones, floods and droughts. Efforts to track and respond to both elements of change can learn a great deal from the expertise and tools already developed within the natural disaster community.

Particular strengths exist in different world regions. For example, the European and North American rural development agencies could learn from work developed in Africa and Asia on tracking livelihood sustainability and slow onset disaster that is linked to changing environmental baselines (for example in drought vulnerability assessment). Similarly, there is much technological skill that could be transferred from the global North to the global South to aid the monitoring of physical processes, and to build appropriate governance regimes to maximise opportunities for adaptation and risk reduction.

As the climate change community continues to place more emphasis on adaptation in addition to the established discussion on mitigation, so the natural disaster community should play an enhanced role.

It is important that the mitigation agenda is not overshadowed by adaptation. The Kyoto Protocol has advanced a set of policy tools that aim to make national development strategies sensitive to their contribution to global climate change risk. Following the same logic, this Report argues for development planning to take up decision-making and information tools that will build sensitivity to disaster risk processes. At the local level in particular, this will require a focus on building capacity for adaptation as proactive risk management.

Climate change will affect most aspects of life. Therefore, it is also important that guiding principles be established for ensuring the mainstreaming of climate change concerns within ongoing human development practices. Key sectors of economic planning — agriculture, tourism, land-use planning, public health, environmental management and basic infrastructure provision — will all need to take climate change into consideration. But mainstreaming efforts might also need to incorporate foreign relations and immigration or emigration policy, as well as resettlement schemes linked to restructuring of the economy. In all of these efforts, lessons gained from natural disaster risk management can form a rapidly accessible resource from which to build tool kits for adaptation.

4.2.4 Managing the multifaceted nature of risk

Natural hazard is one among many potential threats to life and livelihood.

Often, those people and communities most vulnerable to natural hazards are also vulnerable to other sources of hazard. Livelihood strategies for many people are all about playing off risks from multiple hazards sources — economic, social, political, environmental. From this perspective, the increase in perceived risk accruing to an individual or group from not investing time or energy in natural hazard risk reduction, may be an accepted cost in the face of more immediate needs for security from economic collapse, social violence and conflict. When choices are limited, energy is spent on coping with the most immediate of threats.

Analysis in Chapter 2 has shown the value of an integrated approach to risk assessment as a step towards integrated risk reduction. This is not a new idea. Complex political emergencies have for some time been recognised as containing many different drivers of risk, with natural hazard as one possibility. Some key hazards were identified in Chapter 3 — disease (HIV/AIDS, malaria, tuberculosis), landmines and internally displaced people. To this list, we could add small arms, terrorism and crime as risk elements that play out with vulnerability to natural hazard.

From a disaster risk reduction perspective, multi-hazard approaches are uncommon. Perhaps with the exception of work on drought and rural crisis that includes political emergencies and HIV/AIDS. There is a need to explore the relationships between natural hazards with other sources of hazard in the accumulation of risk as a precursor to developing an integrated disaster risk reduction approach.

National level Poverty Reduction Strategy Papers (PRSPs) offer a timely opportunity for factoring multiple-hazard perspectives into development planning.

4.2.5 Compensatory risk management

In addition to reworking the disaster-development relationship, which this Report hopes to make a contribution towards, a legacy of risk accumulation exists today and there is a need to improve disaster preparedness and response.

The agenda proposed in this Report is one of reform in the disaster risk sector and a reorientation towards the long-term management of disaster risk within sustainable development. This is needed over the medium-term to contribute towards the meeting of the Millennium Development Goals. But the time-span for change is likely to be best measured in decades and generations rather than years.

Within this long-term agenda of reform,existing risks remain to be managed. Indeed, development actions of yesterday and today will continue to shape the accumulation of disaster risk for the foreseeable future. Chapter 3 of this Report outlined an array of good practices that can be used to reset the balance between development and disaster risk. Ongoing disaster risk needs to be addressed using the whole gamut of existing good practices.

Large populations remain at risk with only partial access to disaster risk management tools. Such tools include those aimed at reducing exposure to hazard events through preparedness planning and early warning systems; tools that spread losses through insurance mechanisms, including mechanisms developed for low-income groups and informal settlement dwellers; and tools to help people bear disaster impacts, including policies aimed at enhancing livelihood sustainability. This is by no means an exhaustive list and there remains great scope for the exchange of best practice and for innovation.

As local contexts continue to filter the impacts of global climate change and economic globalisation, there will be an ongoing need for innovation and learning to cope with the changing manifestation of disaster risk at the local level.

4.2.6 Gaps in knowledge for disaster risk assessment

A first step towards more concerted and coordinated global action on disaster risk reduction must be a clear understanding of the depth and extent of hazard, vulnerability and disaster loss.

Where data on sub-national distributions of disaster losses exists, it suggests that a large number of small- and medium-sized disasters and sub-disaster scale loss events associated with natural hazards are unfolding below the level of global observatories. The critical policy significance of these events is their contribution to the accumulation of risk and situations where livelihoods and health are eroded to a point at which individuals or communities become susceptible to large-scale loss.

Global databases and risk assessments would carry additional value if local and sub-national databases using uniform data collection and analysis frameworks were available. The lack of such databases makes it impossible to accurately trace the changing geography of risk and track factors shaping the production of vulnerability and hazard, both within countries and between scales. A focus on global-scale trends and distributions of risk is useful, but tells only part of the development and disaster risk story.

Below the national level exist a rapidly growing array of tools to measure vulnerability and hazard as well as record disaster events and loss for many countries and communities. These tools have been developed with particular local contexts in mind. The number and variety of tools available suggests that a next stage in the maturing of disaster risk assessment could be attempts to combine information and begin to piece together the jigsaw of local human development and disaster risk experiences at the sub-national and national levels.The possibility of knowledge accumulated from the bottom up meeting global assessments of risk and vulnerability offers an exciting prospect for verifying assumptions and findings made at both levels for disaster and development policy-making.

The mainstreaming of disaster risk assessment into the ongoing development planning processes can build on the wealth of methodologies already available and on administrative structures already in place at the local, national and global scales.

A great deal of data is collected or known at the local scale, but structures are not in place for the centralised collation of this material at the national, let alone global scales. Local governments, line ministries of central governments and networks of non-governmental and community-based organisations all have roles to play in the developing of shared reporting conventions and methods that will maximise the amount of data that can be used for strategic policy-making.

In many cases individual networks of organisations are already commencing the task of reforming data collection (such as the IFRC), but broader cooperation is needed. Some important steps forward have been made in networking disaster risk datasets and examples are provided in this Report. The journey is, however, in its early stages. The prospects for data collection to support data-informed disaster-development policy-making are exciting.

Specific recommendations towards this end are to:

1. **Enhance global indexing of risk and vulnerability, enabling more and better intercountry and interregional comparisons.**

A number of global level projects have begun to map intercountry and interregional comparisons of risk and vulnerability. There is scope here to share methodological experiences and data.

A future goal, but one that should be addressed in this initial period of modelling, is to construct models around a uniform central language of assumptions and definitions in order to build multiple-risk and vulnerability assessments.

Broadening the array of data collected nationally for global comparisons to include key information needed for risk assessment (number of trained paramedics, number and capacity of active community disaster response groups, etc.) and vulnerability factors (armed conflict, governance, social capital, epidemiology). This would increase the quality of global level assessments. The process of preparation of the DRI shows just how far we are from being able to draw a complete picture of comparative national risk.

2. **Support national and sub-regional risk-indexing to enable the production of information for national decision makers.**

The DRI is moving towards building a global picture of disaster risk. Bringing this work together with sub-national assessments will provided added value. If disaster risk management is to move from a reactive agenda of disaster response to embrace disaster risk-sensitive development planning, national level data is essential. This is needed to target policy and track shifting patterns of hazard and vulnerability. Vulnerability will be shaped by a myriad of forces —such as the global economy, global climate change, internal migration patterns, local environmental resource use and community development interventions — that constantly reconfigure geographies of risk.

3. **Develop a multi-tiered system of disaster reporting.**

The vision is of a unified global system of disaster reporting that connects nationally maintained country databases to a global database that is administered through international institutions and made accessible to the public. A number of stages would be required to make this a reality. A preliminary survey of existing databases to find out what information is already available at the national level, and then make this information available at the global level, would be appropriate. An agreed system for generating a global identifier for each disaster event would be needed. Reporting standards and software would have to be developed to promote data compatibility across national datasets. Skills training would be needed to establish databases in countries where they are not already present.[2]

It is particularly important to establish and standardise a methodology for estimating the socio-economic losses associated with medium- and small-scale disaster events. Such a method exists that works very well for larger-scale disasters, but it could be simplified for more localized applications. In general, economic losses need to be more routinely assessed and reported.

None of these requirements are unachievable and the opportunities offered by such a dataset for strategic international and national disaster policy planning are considerable.

4. Support context-driven risk assessment.

The dynamic qualities of forces shaping risk mean that assessment tools need constant refinement. This is demonstrated by the recent recognition of urban areas as places of high risk. This realisation began a revision of assessment and intervention tools initially developed for rural vulnerability work. Some excellent advances have been made in this regard.Keeping track of new places and social groups at risk is only half of the story. As policy perspectives or background socio-economic structures and physical systems change through time, so will assessment methods need to evolve. Sensitivity to context is a priority for locally meaningful assessment tools, but this needs to be weighed against the need to generate data for sharing along the assessment production chain.

A Final Word

The aim of this Report has been to map out the ways in which development can lead to disaster, just as disaster can interrupt development. The DRI work has shown that billions of people in over 100 countries are periodically exposed to at least one of the hazards studied, with an average of 67,000 deaths annually (184 deaths each day). The high number of people exposed to natural hazard shows the scale of connection between disasters and development. Recorded deaths provide a tip-of-the-iceberg measurement of the extent to which past development decisions have prefigured risk.

The medium-term goal of meeting the MDGs and the longer–term goal of moving towards more sustainable pathways for development need to take disaster risk into account. The Recommendations have highlighted a number of emerging agendas in disaster risk management that offer great potential for integrating disaster risk and development planning. They also point at achievable policy and project actions that can be undertaken to reduce risk in development.

Most fundamental is the role of governance at all scales from the local to the global. A balance between equity and efficiency in the distribution of decision-making power and in making decisions will need to be kept. A concern for governance dovetails into more generic development planning policy. Like many of the proposals, the argument is for a change in emphasis and a broadening of development worldviews to take disaster risk seriously, rather than a call for development planning perspectives to be rewritten. While it may be true that core elements of dominant development paradigms are the root causes for development prefiguring risk, this Report has focused on what can be achieved within existing development approaches.

A particular opportunity for mainstreaming disaster risk reduction into development planning is provided during the reconstruction periods after large-scale disaster events. These are periods where social and political structures as well as physical infrastructure can be rebuilt to enhance quality of life and reduce future disaster risk.

Natural disaster risk reduction can provide a useful basis for adapting to climate change.Bringing the disaster and climate change risk agendas and communities together should be a priority. This will be facilitated by the proactive, adaptive mode of risk reduction championed in this Report, which has much in common with the orientation of policy work on adaptation to climate change.

We live our lives in the context of multiple everyday risks. The periodic nature of natural disaster risk means it is often easily overlooked until it is too late and accumulated risk provokes disaster. Local risk reduction will need to be sensitive to the multiple sources of competing risks people face. Governance regimes need to work to reconcile the pressing need to respond to frequent and everyday risks, while avoiding the creeping vulnerability that can lead to disaster risk.

The focus of this report has been on proactive strategies for reducing future risk. However, today we live with the accumulated risk of past development pathways. Disaster preparedness and response should not be seen in any lesser light. Our argument is to compliment compensatory risk management with a prospective or adaptive approach that can support development without building future disaster risks.

The policy agendas supported in this Report require refined and more complete data. Current global efforts signify a substantial step in the right direction towards producing a globally accessible disaster database with national and sub-national resolution.Equally, the sub-national databases reviewed in this Report provide examples of existing good practice that could be usefully replicated among societies at high disaster risk.

The DRI exercise has contributed by making the first global assessment of disaster risk exposure and human vulnerability. The process of mapping disaster risk as presented in this Report has only just begun. But the message is clear. The work of linking disaster risk reduction to development planning offers great potential for advancing the cause of human development.

1. Gilbert and Kreimer 1999. "Learning from the World Bank's Experience of Natural Disaster Assistance," Urban Development Division, Working Paper Series 2, World Bank.
2. ISDR Working Group 3 on Risk Vulnerability and Impact Assessment. Improving the Quality, Coverage and Accuracy of Disaster Data: A Comparative Analysis of Global and National Datasets. 24 October 2002.

TECHNICAL ANNEX

The Technical Annex provides supporting material on methodologies and results to supplement the main body of the Report. In particular, it provides background on the statistical work undertaken in the development of the Disaster Risk Index (DRI).

This is a detailed account of the work that was carried out in the DRI, the challenges that require further attention and the potential that exists for further work.

T.1 Definition of Statistical Terms

In the Glossary, we have included a set of key terms which are referred to throughout the Report. In order to aid comparability, in most cases we stay close to those used in the ISDR Secretariat publication *Living in Risk.* At the same time, the development of the DRI required the adoption of specific working definitions that guided the statistical analysis undertaken.

In this section, we present an extract of terms from the Glossary followed by the specific working definition of the term used in the development of the DRI.

Natural Hazard: Natural processes or phenomena occurring in the biosphere that may constitute a damaging event. Hazardous events vary in magnitude, frequency, duration, area of extent, speed of onset, spatial dispersion and temporal spacing.[1]

In the DRI: Natural hazards refer exclusively to earthquake, tropical cyclone, flood and drought. Only frequencies and area of extent were considered in the model.Magnitude is taken into account indirectly when possible. Secondary hazards triggered by the primary hazards mentioned above (for example, landslides triggered by earthquakes) are subsumed in the primary hazard.

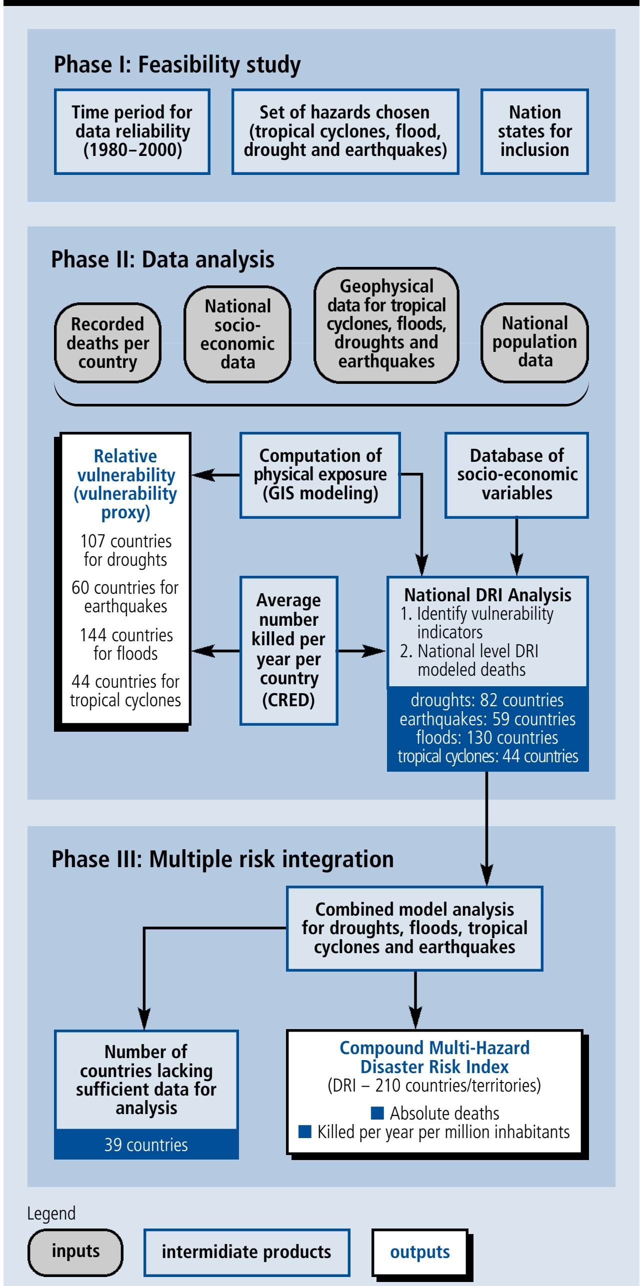
Physical Exposure: Elements at risk, an inventory of those people or artefacts that are exposed to the hazard.[2]

In the DRI: Physical exposure refers to the number of people located in areas where hazardous events occur combined with the frequency of hazard events.

Human Vulnerability: A human condition or process resulting from physical, social, economic and environmental factors, which determine the likelihood and scale of damage from the impact of a given hazard.

In the DRI: Human vulnerability refers to the different variables that make people more or less able to absorb the impact and recover from a hazard event. The way vulnerability is used in the DRI means that it *also* includes anthropogenic variables that may increase the severity, frequency, extension and unpredictability of a hazard.

FIGURE T.1 FLOW CHART OF THE GLOBAL RISK AND VULNERABILITY TREND PER YEAR (GRAVITY) PROJECT



Natural Disaster: A serious disruption triggered by a natural hazard causing human, material, economic or environmental losses, which exceed the ability of those affected to cope.

In the DRI: Disasters are a function of physical exposure and vulnerability.

Risk: The probability of harmful consequences or expected loss (of lives, people injured, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between natural or human-induced hazards and vulnerable conditions. Risk is conventionally expressed by the equation Risk = Hazard + Vulnerability.

In the DRI: Risk refers exclusively to loss of life and is considered as a function of physical exposure and vulnerability.

T.2 Sourcing Data

T.2.1 EM-DAT Database

The DRI exercise is calibrated against the mortality data in the EM-DAT global disaster database. It is important to be clear about the data collection and management methods employed by EM-DAT.

The Centre for Research on the Epidemiology of Disasters (CRED) maintains the EM-DAT database at the University of Louvain in Belgium. Events that conform to a consistent definition of a disaster are included in the database. Such events meet at least one of the following criteria: 10 or more people reported killed; 100 people reported affected; a call for international assistance; and/or a declaration of a state of emergency. Information on losses comes from secondary sources (government reports, the International Federation of the Red Cross and Red Crescent Societies (IFRC) and other disaster relief agencies, Reuters, reinsurance company assessments) and is cross-checked where possible. These criteria exclude smaller loss events which are not considered disasters.

One important quality of EM-DAT is its management by an independent academic institution that encourages public access and scrutiny of the dataset. Great care is taken to verify disaster reports and emphasis is placed on the higher confidence that can be placed on the accuracy of deaths over those injured, made homeless or affected by disaster, although information is also made available for these categories.

Two other global disaster databases are maintained by the Munich Re Group and Swiss Reinsurance Company, but are not publicly available. A study by CRED (commissioned by the ProVention Consortium[3]) carried out a comparison of EM-DAT, Swiss Re and Munich Re natural disasters databases for four countries (Honduras, Mozambique, India and Viet Nam) between 1985 and 1999. Although the report stated that all three databases furnish the world community with 'acceptable levels of data on disasters',[4] it discovered significant variations among these datasets in both the events recorded and losses reported.

These differences were explained by differences in recording practice: what date each event is given, differences in classificatory methodology for each hazard type (a problem if one hazard triggers another) and the multiple entry of a single disaster event. As a result, the study found considerable differences between the datasets in the number of people affected (66 percent) and to a lesser extent the number of deaths (37 percent) and physical damage (35 percent). This is not surprising, since the definition of people affected varies enormously from disaster to disaster and from reporting source to reporting source.It is the most difficult impact variable to quantify and for this reason has not been used in the DRI work.The report also showed that the differences between the databases reduced significantly with time. This reflects EM-DAT's practice of reviewing its databases to incorporate updated information as it becomes available, even years after an event. A main weakness with global disaster data is the lack of standardised methodologies and definitions.This weakness is being addressed through the development of a unique global identifier for disaster reporting, the GLIDE system discussed in Chapter 2.

As mentioned above, EM-DAT explicitly excludes events where the loss is below defined threshold levels. A study undertaken on behalf of the ISDR Working Group 3 on Risk, Vulnerability and Impact Assessment, compared national disaster databases developed using the DesInventar methodology with the EM-DAT databases in four countries (Colombia, Chile, Panama and Jamaica). In all four countries,small-scale disasters with losses below the EM-DAT threshold represented a variable proportion of total disaster loss. Additionally, the national databases contained data on a number of medium-scale disasters that were above the EM-DAT threshold, but which were not captured by international reporting. It is impossible to arrive at a firm conclusion from a four-country study regarding what percentage of total disaster loss is not captured by international reporting, and in any case this will vary from country to country. Again, the adoption of a unique identifier such as GLIDE in both national and global databases like EM-DAT should progressively improve the consistency of disaster reporting.

Given that the DRI is calibrated against mortality data from EM-DAT, under- or over-reporting of this variable in EM-DAT would affect the DRI results. However, the DRI takes into account the varied reporting for individual disasters by basing its analysis on average losses over a 20-year period (1980-2000). The EM-DAT database provides a very good sample of total disaster loss in this period with a national level of resolution.

This period provides a reasonable length of time to account for fluctuation in the occurrence of most hazard types and also coincides with the most reliable period of data collected in EM-DAT. Figure T.2 shows the total number of disasters recorded by EM-DAT from 1900 to 2000.The upward trend at first suggests an exponential increase in disaster frequency. However, improvement in disaster reporting is a substantial

FIGURE T.2 DISASTERS RECORDED BY EM-DAT

Source: EM-DAT: The OFDA/CRED International Disaster Database contributing factor.[5] While one cannot rule out that the number of hydrometeorological hazard events may have increased, the upward trend in reported disasters is more likely to be tied to improvements in telecommunication technology and the increasingly global coverage of different information networks. This makes the reporting and recording of disaster losses more possible today than in the past.

T.2.2 Choice of hazard types

The decision to limit the DRI to earthquake, tropical cyclone, flood and drought was based on two factors. First, the dominance of these hazard types in being associated with lives lost to disaster in past records (94.43 percent). Secondly, the availability of usable geophysical and hydrometeorological data to model each hazard's comparative extent and potential severity of impact. Data had to be available at the global level but detailed enough to map risk within each country.

During a preliminary investigation,volcanic eruptions were also considered. They were finally excluded because of the complexity of modelling the spatial extent of volcanic hazard events. Other types of hazards that may lead to disasters and influence the process of human development, such as technological and biological hazards, are not covered by the DRI, nor are natural hazards with more prominence at the local scale such as landslides. These could be included in the future when global datasets of events with national resolution come into use.

T.2.3 Choice of country cases

The DRI exercise aims to include all sovereign states in its analysis.This is compromised in two ways. First, there are varying levels of data availability. The decision here was to include all states from the outset, but discount those with inadequate data from detailed analysis. This partly accounts for the uneven number of states entered into the hazard-specific analyses. Secondly, a number of territories are classified as dependent territories or overseas departments. Such dependencies are often small islands or enclaves geographically distant from, but politically and administratively tied to, sovereign states such as France, the United Kingdom, USA or China. Overseas territories and sovereign states often exhibit very different socio-economic and environmental characteristics and hazard profiles. Where possible such territories have been analysed in their own right.

T.2.4 Outline formula and method for estimating risk and vulnerability

The formula used for modelling risk combines its three components. Risk is a function of hazard occurrence probability, the element at risk (population) and vulnerability. The equation below was made for modelling disaster risk.

0 (hazard) x population x vulnerability = 0 (risk)

The three factors used to construct this statistical explanation of risk were multiplied with each other. This meant that if the hazard was null, then the risk was null. The risk was also null if nobody lived in an area exposed to hazard (population = 0). The same situation held if the population was invulnerable (vulnerability = 0, induce a risk = 0).

From this, a simplified equation of risk[a] was constructed:

EQUATION 1 RISK

EQ1 $$R = H \cdot Pop \cdot Vul$$

Where
R is the risk (number of killed people.
H is the hazard, which depends on the frequency and strength of a given hazard
Pop is the population living in a given exposed area
Vul is the vulnerability and depends on the socio-politial-economical context of this population

Hazard multiplied by the population was used to calculate physical exposure.

EQUATION 2 RISK EVALUATION USING PHYSICAL EXPOSURE

EQ2 $$R = PhExp \cdot Vul$$

Where
PhExp is the physical exposure, i.e. the frequency and severity multiplied by exposed population

Physical exposure was obtained by modelling the area affected by each recorded event. Event frequency was computed by counting the number of events for the given area, divided by the number of years of observation (in order to achieve an average frequency per year). Using the area affected, the number of people in the exposed population was extracted using a Geographical

a. The model uses a logarithmic regression, the equation is similar but with exponent to each of the parameters.

EQUATION 3 ESTIMATION OF THE TOTAL RISK

EQ3 $$Risk_{Tot} = \sum(Risk_{Flood} + Risk_{Earthquake} + Risk_{Volcano} + Risk_{Cyclone} + ...Risk_n)^b$$

Information System (GIS). The population affected multiplied by the frequency of a hazard event for a specified magnitude provided the measure for physical exposure.

Socio-economic variables that could be statistically associated with risk were identified by replacing the risk in the equation with deaths reported in EM-DAT. A statistical analysis was then run to identify links between socio-economic and environmental variables, physical exposure and observed deaths.

The magnitude of events was taken into account by drawing a threshold above which an event is included. In the case of earthquakes,the threshold was placed at 5.5 on the Richter scale. Then the magnitude was partially taken into account by approaching the size of the area affected in relation to the magnitude, for the computation of physical exposure. Estimating event magnitude for use in global assessments is an area where there is great scope for improvement.

Scores for aggregated hazard deaths were calculated at the national level. Expected losses due to natural hazards were equal to the sum of all types of risk faced by a population in a given area. This is summarised in Equation 3 above.

The multi-hazard risk for a country required calculating an estimate of the probability of the occurrence and severity of each hazard, the number of persons affected by it, and the identification of the population's vulnerability and coping capacities. This is very ambitious and not achievable with present data constraints. However the aim is to provide an approach built on existing data that will be refined in subsequent runs of the DRI.

T.3 Choice of Indicators

T.3.1 Spatial and temporal scales

The DRI exercise was performed on a country-by-country basis for the 249 countries defined in the GEO reports.[6]

The socio-economic variables used in the analysis of risk needed to be available to cover the 21-year period under analysis. This period was from 1980 to 2000. The starting date was set at 1980 because access to information (especially on victims) was not considered reliable or comparable before this year. The variables introduced in Equation 2 were aggregate figures (sum or average) of the available data for that period, with the following major exceptions:

- Earthquake frequencies were calculated over a 36-year period,due to the longer return period of this type of disaster. The starting date for the first global coverage on earthquakes measurement is 1964.
- Cyclones frequencies were based on annual probabilities provided by the Carbon Dioxide Information Analysis Center (CDIAC).[7]
- HDI was available for the following years: 1980, 1985, 1990, 1995 and 2000. However, algorithms were applied for computation of every year between 1980 and 2000.
- Population by grid cell (for physical exposure calculations) was available for 1990 and 1995.
- The Corruption Perception Index (CPI) was available for 1995 to 2000.

T.3.2 Risk indicators

Risk can be expressed in different ways (for example by the number of people killed, percentage killed or percentage killed as compared to the exposed population). Each measure has advantages and inconveniences (see Table T.1 on the following page).

The DRI work used two indicators for each hazard type: the number of killed and killed per population. The third indicator is used to indicate relative vulnerability. Exposed populations to different hazards should not be compared as stated in the Report without standardisation.

T.3.3 Vulnerability indicators

Table T.2 (see following page) hows those socio-economic and environmental variables chosen to represent eight separate categories of vulnerability.

b. In the case of countries marginally affected by a hazard type, the risk was replaced by zero if the model could not be computed for this hazard.

TABLE T.1 ADVANTAGES AND DISADVANTAGES OF RESPECTIVE RISK INDICATORS

Indicators for risk	Advantages	Inconveniences
Number of killed	Each human being has the same 'weight.'	10,000 people killed split between 10 small countries does not appear in the same way as 10,000 killed in one country. Smaller countries are disadvantaged.
Killed/Population	Allows for comparisons between countries. Less populated countries have the same weight as more populated countries.	The 'weight' of each human being is not equal, e.g. one person killed in Honduras equals 160 killed in China.
Killed/Population exposed	Regional risk is highlighted, even though the population affected is a smaller portion of the total national population.	This may highlight local problems that are not of national significance and give the wrong priority for a selected country.

TABLE T.2 VULNERABILITY INDICATORS

Categories of Vulnerability	Indicators	Drought	Flood Earthquakes Cyclones	Source[c]
Economic	Gross Domestic Product per inhabitant at purchasing power parity	X	X	WB
	Human Poverty Index (HPI)	X		UNDP
	Total debt service (% of the exports of goods and services)		X	WB
	Inflation, food prices (annual %)		X	WB
	Unemployment, total (% of total labour force)		X	ILO
Type of economic activities	Arable land (in thousand hectares)		X	FAO
	% of arable land and permanent crops		X	FAO
	% of urban population		X	UNPOP
	% of agriculture's dependency for GDP	X		WB
	% of labour force in agricultural sector	X		FAO
Dependency and quality of the environment	Forests and woodland (in % of land area)		X	FAO
	Human-Induced Soil Degradation (GLASOD)	X	X	FAO/UNEP
Demography	Population growth		X	UNDESA
	Urban growth		X	GRID[d]
	Population density		X	GRID[e]
	Age dependency ratio		X	WB
Health and sanitation	% of people with access to improved water supply (total, urban, rural)	XXX		WHO/UNICEF
	Number of physicians (per 1,000 inhabitants)		X	WB
	Number of hospital beds		X	WB
	Life expectancy at birth for both sexes		X	UNDESA
	Under-five-years-old mortality rate	X		UNDESA
Early warning capacity	Number of radios (per 1,000 inhabitants)		X	WB
Education	Illiteracy rate		X	WB
Development	Human Development Index (HDI)	X	X	UNDP

Source: UNDP/UNEP

c. FAOSTAT, the database of the Food and Agriculture Organisation (FAO); GRID, the Global Resource Information Database of UNEP; WB, World Development Indicators of the World Bank; Human Development Report of UNDP; ILO, International Labour Office; UNDESA, the UN Dept. of Economic and Social Affairs/Population Division. Most of the data were reprocessed by the UNEP Global Environment Outlook Team. Figures are available at the GEO Data Portal (UNEP), http://geodata.grid.unep.ch

d. Calculated from UN Dept. of Economic and Social Affairs data.

e. Calculated from UNEP/GRID spatial modelling based on CIESIN population data.

TABLE T.3 DATA SOURCES FOR HAZARDS

Hazard type	Data source
Earthquakes	Council of the National Seismic System (as of 2002), Earthquake Catalog, http://quake.geo.berkeley.edu/cnss/
Cyclones	Carbon Dioxide Information Analysis Centre (1991), A Global Geographic Information System Data Base of Storm Occurrences and Other Climatic Phenomena Affecting Coastal Zones, http://cdiac.esd.ornl.gov/
Floods	U.S. Geological Survey (1997), HYDRO1k Elevation Derivative Database, http://edcdaac.usgs.gov/gtopo30/hydro/
Droughts (physical drought)	IRI/Columbia University, National Centres for Environmental Prediction Climate Prediction Centre (as of 2002), CPC Merged Analysis of Precipitation (CMAP), monthly gridded precipitation, http://iridl.ldeo.columbia.edu/

TABLE T.4 DATA SOURCES FOR VICTIMS, POPULATION AND VULNERABILITY VARIABLES

Theme	Data source
Victims (killed)	Université Catholique de Louvain (as of 2002), EM-DAT: The OFDA/CRED International Disaster Database, http://www.cred.be/ (for droughts, victims of famines were also included on a case by case basis by UNDP/BCPR)
Population (counts)	CIESIN, IFPRI, WRI (2000), Gridded Population of the World (GPW), Version 2, http://sedac.ciesin.org/plue/gpw/; UNEP, CGIAR, NCGIA (1996), Human Population and Administrative Boundaries Database for Asia, http://www.grid.unep.ch/data/grid/human.php
Vulnerability factors	
Human Development Index (HDI)	UNDP (2002), Human Development Indicators, http://www.undp.org/
Corruption Perceptions Index (CPI)	Transparency International (2001), Global Corruption Report 2001, http://www.transparency.org/
Soil degradation (% of area affected)	ISRIC, UNEP (1990), Global Assessment of Human-Induced Soil Degradation (GLASOD), http://www.grid.unep.ch/data/grid/gnv18.php
Other socio-economic variables	UNEP/GRID (as of 2002), GEO-3 Data portal, http://geodata.grid.unep.ch/ (data compiled from World Bank, World Resources Institute, FAO databases)

The list of factors to be considered for the analysis was set on the basis of the following criteria:

- *Relevance.* Select vulnerability factors (outputs orientated, resulting from the observed status of the population) not based on mitigation factors (inputs, action taken). For example, school enrollment rather than education budget.
- *Data quality and availability.* Data should cover the 1980-2000 period and most of the 249 countries and territories.

Examples of variables that were rejected for these two reasons were the percentage of persons affected by AIDS, the level of corruption and the number of hospital beds per inhabitant.

T.3.4 Data sources

Data sources ranged from universities and national scientific institutions to international data series collected by international organisations. Table T.3 presents the data sources used to obtain data on hazards.

Table T.4 presents the data sources used to obtain data on victims, population and vulnerability variables.

T.4 The Computation of Physical Exposure

T.4.1 General description

Two methods are available for calculating physical exposure. First, by multiplying hazard frequency by the population living in each exposed area. The frequencies of hazards were calculated for different strengths of event, and physical exposure was computed as in Equation 4.

EQUATION 4 COMPUTATION OF PHYSICAL EXPOSURE

EQ $$PhExp_{nat} = \sum F_i \cdot Pop_i$$

Where
$PhExp_{nat}$ is the physical exposure at national level
F_i is the annual frequency of a specific magnitude event in one spatial unit
Pop_i is the total population living in the spatial unit

A second method was used when data on the annual frequency of return of a specific magnitude event was not available. In this case (earthquake), physical exposure was computed by dividing the exposed population by the numbers of years when a particular event had taken place as shown in Equation 5.

EQUATION 5 PHYSICAL EXPOSURE CALCULATION WITHOUT FREQUENCY

EQ5 $$PhExp = \sum \frac{Pop_i}{Y_n}$$

Where

Pop_i is the total population living in a particular buffer, the radius of which from the epicentre varies according to the magnitude

Y_n is the length of time in years

PhExp is the total physical exposure of a country, in other words the sum of all physical exposure in this country

EQUATION 6 COMPUTATION OF CURRENT PHYSICAL EXPOSURE

EQ6 $$PhExp_i = \sum \frac{Pop_i}{Pop_{1995}} \cdot PhExp_{1995}$$

Where

$PhExp_i$ is the physical exposure of the current year

Pop_i is the population of the country at the current year

Pop_{1995} is the population of the country in 1995

$PhExp_{1995}$ is the physical exposure computed with population as in 1995

Once the area exposed to a hazard was computed — using UNEP/GRID-Geneva methods for earthquakes, floods and cyclones and using a method for drought from the International Research Institute for Climate Prediction (IRI) — then the exposed population was calculated for each exposed area. This number was then aggregated at the national level to come to a value for the number of exposed people over the last 21 years for each hazard type.

Depending on the type of hazard and the quality of data, different methods were applied to estimate the size of populations exposed to individual hazards. Population data was taken from CIESIN, IFPRI and WRI Gridded Population of the World (GPW, Version 2) at a resolution of 2.5'[f] (equivalent to 5 x 5 km at the equator). This was supplemented by the Human Population and Administrative Boundaries Database for Asia (UNEP) for Taiwan and CIESIN Global Population of the World Version 2 (country level data) for ex-Yugoslavia.These datasets reflect the estimated population distribution for 1995. Since population growth is sometimes very high in the 1980-2000 period, a correction factor using country totals was applied in order to estimate current physical exposures for each year as follows (see Equation 6).

Due to the resolution of the dataset, the population could not be extracted for some small islands. This has meant some small islands had to be left out of parts of the analysis.This is a topic for further research (see recommendations in the Conclusions of the Technical Annex).

The main challenge lay in the evaluation of areas exposed to particular hazard frequency and intensity. At the global scale, data was not complete. Expert opinion was used to review the process of building datasets. Of the four hazards studied, only in the case of floods was it necessary to design a global dataset. This was constructed by linking CRED information with USGS watersheds. Drought maps were provided by IRI. For the other hazards, independent global datasets had already been updated, compiled or modelled by UNEP/GRID-Geneva and were used to extract population. The Mollweide equal-area projection was used when calculations of areas were needed.

T.4.2 The case of earthquake

A choice was made to produce seismic hazard zones using the seismic catalogue of the Council of the National Seismic System. The earthquakes records of the last 21 years (1980-2000) were grouped in five magnitude classes using a buffer with a radius from the epicentre that varied according to the magnitude class (see Table T.5).

The values in Table T.5 show estimated ground-motion duration for specific acceleration and frequency ranges, according to magnitude and distance from the epicentre.[8] Numbers in bold in Table T.5 show the duration for a particular acceleration and frequency range between the first and last acceleration excursions on the record greater than a given amplitude level (for example, 0.05 g).[9]

f. GPW2 was preferred to the ONRL Landscan population dataset despite its five times lower spatial resolution (2.5' against 30") because the original information on administrative boundaries and population counts is almost two times more precise (127,093 administrative units against 69,350 units). Furthermore, the Landscan dataset is the result of a complex model which is not explained thoroughly and which is based, among other variables, on environmental data (land-cover). That makes it difficult to use for further comparison with environmental factors (circularity).

TABLE T.5 LIMITS OF THE RADIUS FOR EARTHQUAKES HAZARD

Distance (km)	Magnitude						
	5.5	6.0	6.5	7.0	7.5	8.0	8.5
10	8	12	19	26	31	34	35
25	4	9	15	24	28	30	32
50	2	3	10	22	26	28	29
75	1	1	5	10	14	16	17
100	0	0	1	4	5	6	7
125	0	0	1	2	2	3	3
150	0	0	0	1	2	2	3
175	0	0	0	0	1	2	2
200	0	0	0	0	0	1	2

Source: [Bolt et al. 1975] Acceleration > 0.05 g = ~ 0,49 m/s2, frequency > 2 Hz

According to these figures, a specific buffer distance was defined for each class of magnitude to limit the area affected by ground motions: 75 km for Magnitude ≤ 6.2, 125 km for M = 6.3 – 6.7, 150 km for M = 6.8 – 7.2, 175 km for M = 7.3 – 7.7, 200 km for M ≥ 7.8.This approach did not take into account local conditions, for instance soil or geo-tectonic characteristics.

Assuming the limitations inherent in a mortality-based conceptual model, there were three key challenges to calculating the earthquake risk index.

The first and most difficult challenge was the necessity to use a restricted time-frame for analysis of risk (1980-2001). Twenty years is a short time-span to analyze the occurrence of geological phenomena such as earthquakes, which are low frequency/high impact events. For this reason, risks are overestimated by the model for some countries and underestimated for others.Armenia provides an example of a high-impact single earthquake in a small-sized country (29,000 square kilometres), with a high population density (117 per square kilometre). The earthquake that affected this former Soviet Republic in 1998 killed 25,000 people, left 514,000 people homeless and prompted the evacuation of almost 200,000 people. The high losses recorded in this event appear to exaggerate Armenia's long-term calculated risk value, in comparison with countries known to be at risk but where no event took place during the time period used to calculate the risk model. An example of this is the Algerian earthquake in 2003, which is later than the period used in the DRI exercise. In order to partly overcome such limitation, frequency was derived using data from 1964-2000 in order to take advantage of the time-span available globally.

Secondly, in the delimitation of areas at risk from individual earthquake zones, it was not possible to consider intervening factors (such as soil types and geology) in the transmission of earthquake energy. In explaining the ground motions of earthquakes and therefore the severity of impact, soil conditions play a major role. Inclusion of this data would have allowed for a more accurate delimitation of areas and thus populations exposed to earthquake risks of various magnitudes and intensities. While values for peak ground acceleration were available from the Global Seismic Hazard Assessment Programme, they did not allow for the calculation of frequencies.Consequently, the analysis was based solely on magnitude values that were taken from the Council of the National Seismic System (CNSS).

FIGURE T.3 POPULATION, INTENSITY AND PHYSICAL EXPOSURE FOR EARTHQUAKES

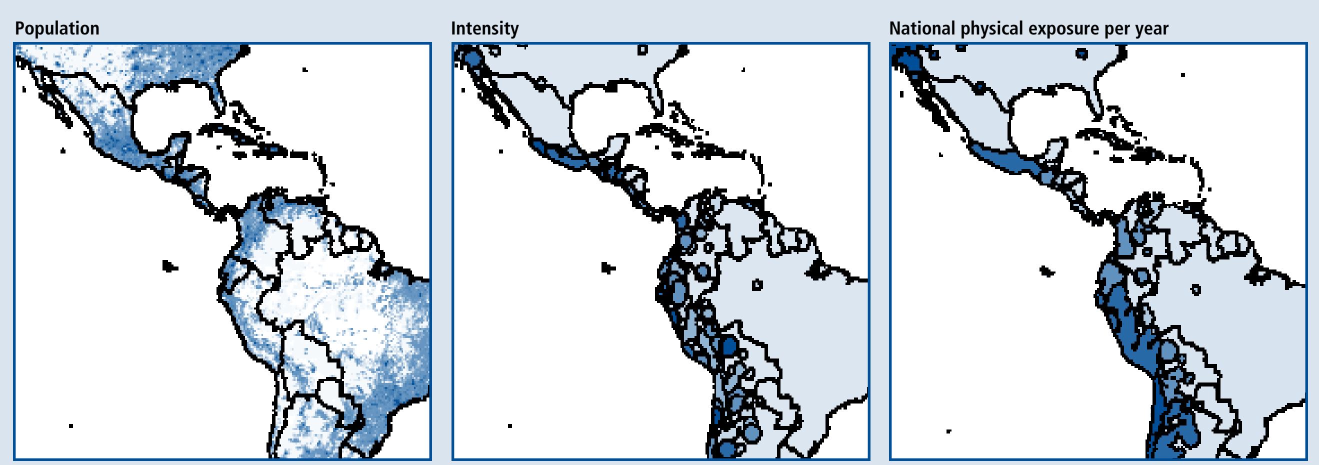


TABLE T.6 WIND SPEEDS AND APPELLATIONS

Wind speeds	Name of the phenomenon
≥ 17 m/s	Tropical storms
≥ 33 m/s	Hurricanes, typhoons, tropical cyclones, severe cyclonic storms (depending on location)
≥ 65 m/s	Super-typhoons

A third and more generic challenge for the risk model was the lack of casualty and death data and a lack of underlying socio-economic and environmental data for some countries. This is particularly problematic for mapping global earthquake risk because some gaps in national level data led to the exclusion of some countries — known to be at particularly high risk from earthquakes — from the calculation of the vulnerability indicators. This was the case for Afghanistan, Sudan, Tajikistan and Guinea. Future improvements in statistical records will enhance the scope of future assessments.

T.4.3 The case of tropical cyclone

The data used to map tropical cyclone hazard areas were produced by the Carbon Dioxide Information Analysis Centre.[10] The spatial unit is a 5 x 5 decimal degrees cell.Return probabilities were based on tropical cyclone activity over a specific record period.Exceptions were made for several estimated values attributed to areas that may present occasional activity, but where no tropical cyclones were observed during the record period.

The Saffir-Simpson tropical cyclones classification is based on the maximum sustained surface wind. Systems with winds of less than 17 m/s are called Tropical Depressions. If the wind reaches speeds of at least 17 m/s, the system is called a Tropical Storm. If the wind speed is equal to or greater than 33 m/s, the system is named, depending on its location:[g] Hurricane, Typhoon, Severe Tropical Cyclone, Severe Cyclonic Storm or Tropical Cyclone. Systems with winds reaching speeds of 65 m/s or more are called Super-typhoons.[11]

The CDIAC provided the probability of occurrence for these three types of events. The average frequency (per year) was computed using Equation 7.

To obtain physical exposure, a frequency per year was derived for each cell. Cells were divided to follow country borders, then population was extracted and multiplied by frequency in order to obtain the average yearly physical exposure for each cell. This physical exposure was then summed by country for the three types of cyclones.

Physical exposure to tropical cyclones of each magnitude was calculated for each country using Equation 5.

There is room for improving the human exposure calculation by more accurate delimitation of exposed population zones for tropical cyclone tracks.Even though accurate zoning was possible for many tropical cyclone-prone countries, data on tracks, central pressure and sustained winds were not available for some heavily populated and high-risk countries, such as India, Bangladesh and Pakistan. While these data exist they were not accessible.

T.4.4 The case of flood

The only global database on floods that was identified was the Dartmouth Flood Observatory, but this database did not cover the time period under study. Due to the lack of information on the duration and severity of floods, only one class of intensity was made. Using the EM-DAT database, a geo-reference of each recorded flood was produced and the watershed related to each flood event was identified. Watersheds affected were mapped for the period 1980-2000. A frequency was derived for each watershed by dividing the total number of events by 21 years. The watersheds were then split to follow country borders. Next,population was extracted and multiplied by the event frequency. The average yearly physical exposure was then summed at a country level using Equation 3.

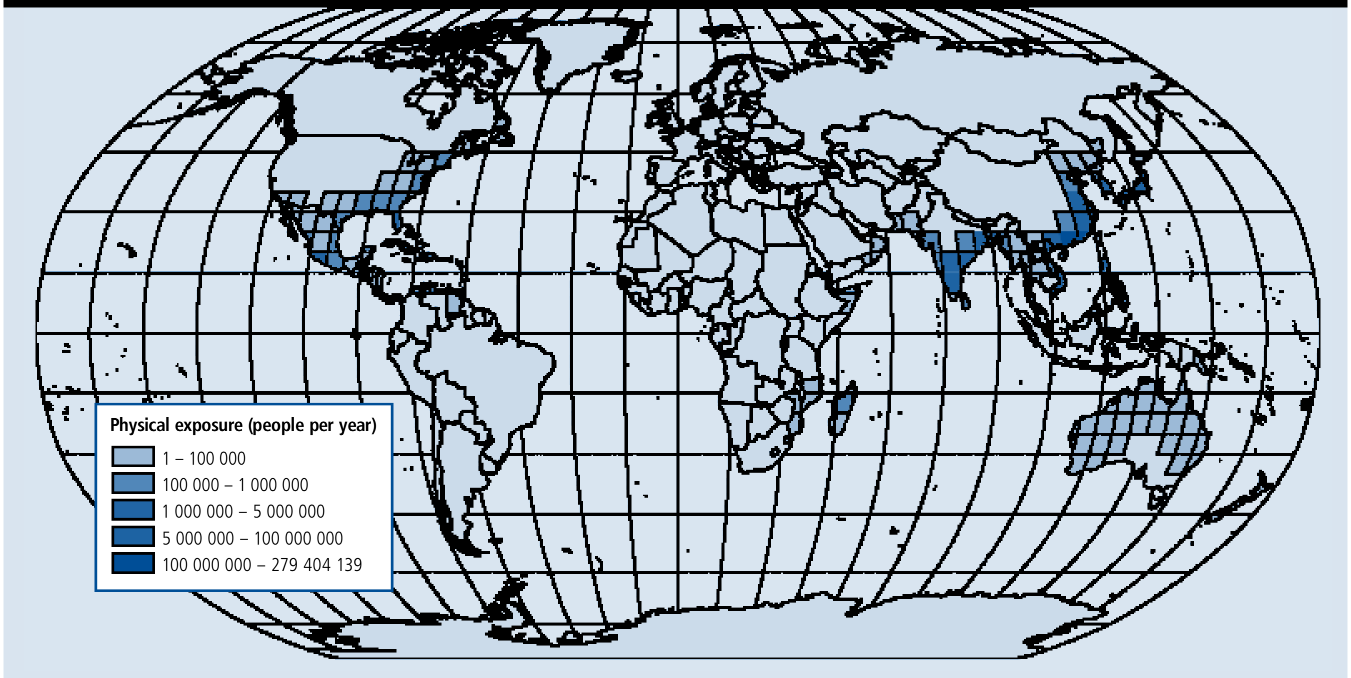
EQUATION 7 FROM PROBABILITY TO ANNUAL FREQUENCY FOR CYCLONES

EQ7 $$E(x) = \lambda = -ln(1 - P(x \geq 1))$$

Where
E(x) is the statistical expectation, i.e. the average number of events per year = λ
P(x) is the probability of occurrence

g. Hurricane: North Atlantic Ocean, Northeast Pacific Ocean east of the dateline, or the South Pacific Ocean east of 160E; Typhoon: Northwest Pacific Ocean west of the dateline; Severe tropical cyclone: Southwest Pacific Ocean west of 160E and Southeast Indian Ocean east of 90E; Severe cyclonic storm: North Indian Ocean; Tropical cyclone: Southwest Indian Ocean; Source: NOAA/AOML, FAQ: Hurricanes, Typhoons and Tropical Cyclones, http://www.aoml.noaa.gov/hrd/tcfaq/tcfaqA.html#A1

FIGURE T.4 AN EXAMPLE OF PHYSICAL EXPOSURE FOR TROPICAL CYCLONES



Source: Carbon Dioxide Information Analysis Centre: A Global Geographic Information System Database of Storm Occurrences and Other Climactic Phenomena Affecting Coastal Zones; CIESIN, IFPRI, WRI: Gridded Population of the World (GPW), Version 2 (population); Compilation and computation by UNEP/GRID-Geneva

Assuming the limitations inherent in a mortality-based conceptual model there were two key challenges to measuring flood risk.

First, there remains a need for refining the calculation of human exposure and vulnerability to floods in the formulation of the DRI. The use of watersheds affected by floods to delimit hazard exaggerates the extent of flood-prone areas, subsequently exaggerating human exposure and diminishing proxies of vulnerability.

Second, in the absence of historical flood event data, annual probabilities of floods should be based on hydrological models rather than being inferred from the flood entries in the EM-DAT database.

T.4.5 The case of drought

Identification of drought

The data used in this analysis consisted of gridded monthly precipitation data for the globe for the period 1979-2001. This dataset was based on a blend of surface

FIGURE T.5 POPULATION, FREQUENCY AND PHYSICAL EXPOSURE FOR FLOODS

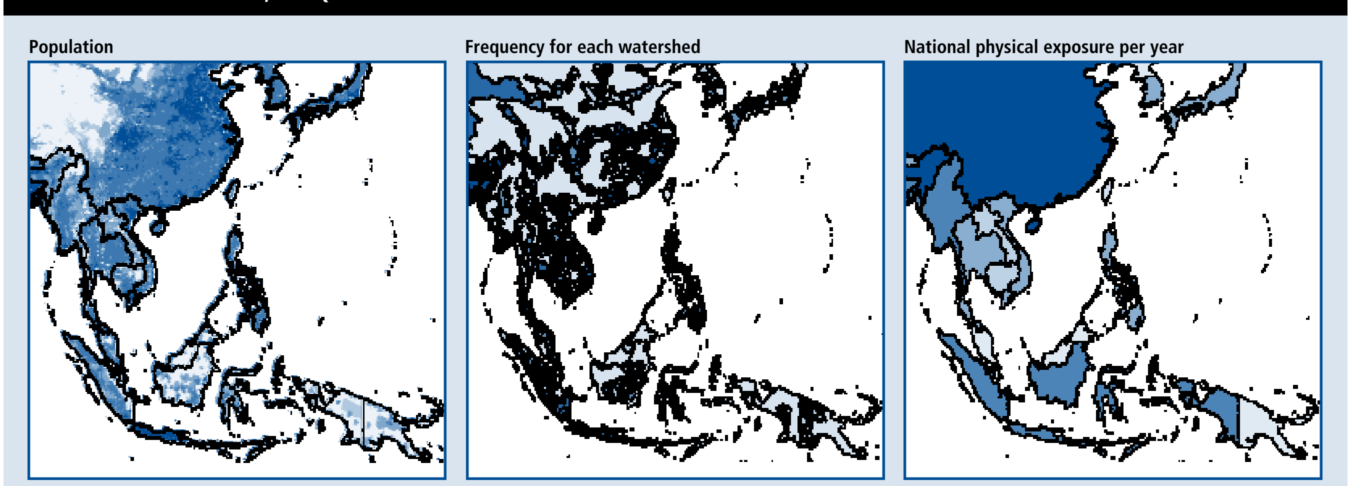


TABLE T.7 DEFINITION OF DROUGHT

Duration	Severity
3 months	90% of median precipitation 1979-2001 (-10%)
3 months	75% of median precipitation 1979-2001 (-25%)
3 months	50% of median precipitation 1979-2001 (-50%)
6 months	90% of median precipitation 1979-2001 (-10%)
6 months	75% of median precipitation 1979-2001 (-25%)
6 months	50% of median precipitation 1979-2001 (-50%)

station observations and precipitation estimates drawn from satellite observations. The first step in assessing exposure to meteorological drought was to compute, for each calendar month, the median precipitation for all grid points between the latitudes of 60S and 70N over the base period 1979-2001 (the 23-year period for which the data was available). Next, for each grid-point, the percent of the long-term median precipitation was computed for every month during the period January 1980 to December 2000. For a given month,grid-points with a long-term median precipitation of less than 0.25 mm/day were excluded from the analysis. Such low median precipitation amounts can occur either during the 'dry season' at a given location or in desert regions. In both cases our definition of drought does not apply.

A meteorological drought event was defined as having occurred when the percent of median precipitation was at or below a given threshold for at least three consecutive months. The different thresholds considered were 50 percent, 75 percent and 90 percent of the long-term median precipitation, with the lowest percentage indicative of the most severe drought according to this method. The total number of events during the period 1980-2000 were thus determined for each grid-point and the results plotted on global maps.

Computation of physical exposure

Using the IRI/Columbia University dataset, physical exposure was estimated by multiplying the frequency of hazard by the population living in an exposed area. The events were identified using different measurements, based on severity and duration as described in Table T.7. For each of the following six definitions, the frequency was then obtained by dividing the number of events by 21 years, thus providing an average frequency of events-per-year.

Physical exposure was computed, as in Equation 5, for each drought definition. The statistical analysis selected the best fit. This was achieved with droughts of three months duration and 50 percent decrease in precipitation.

EQUATION 8 ESTIMATE OF KILLED

EQ8 $$K = C \cdot (PhExp)^{\alpha} \cdot V_1^{\alpha_1} \cdot V_2^{\alpha_2} \dots \cdot V_p^{\alpha_p}$$

Where
K is the number of persons killed by a certain type of hazard
C is the multiplicative constant.
PhExp is the physical exposure: population living in exposed areas multiplied by the frequency of occurrence of the hazard
V_i are the socio-economic parameters
α_i is the exponent of Vi , which can be negative (for ratio)

T.5 Statistical analysis: Methods and results

T.5.1 Defining a multiplicative model

The statistical analysis is based on two major hypotheses. First, that risk can be understood in terms of the number of victims of past hazardous events. Secondly, that the equation of risk follows a multiplicative model as in Equation 8.

Using logarithmic properties, the equation was re-formulated as in Equation 9. This equation creates a linear relationship between logarithmic sets of values. This allows significant socio-economic parameters V_i (with transformations when appropriate) and exponents α_i to be determined using linear regressions.

T.5.2 Detailed process

Data on victims

Numbers of killed were derived from the EM-DAT database and computed as the average number killed per year during the 1980-2000 period.

EQUATION 9 LOGARITHM PROPERTIES

EQ9 $$\ln(K) = \ln(C) + \alpha(PhExp) + \alpha_1 \ln(V_1) + \alpha_2 \ln(V_2) + \dots \alpha_p \ln(V_p)$$

Filtering the data

The statistical models for each disaster type were based on subsets of countries, from which were excluded:

- Countries with no physical exposure or any victims reported (zero or null values).
- Countries where it was not possible to confirm data on physical exposure (e.g. the case of Kazakhstan for floods) or socio-economic factors.
- Countries with low physical exposure (less than 2 percent of the total population) because socio-economic variables were collected at a national scale. The exposed population needs to be of some significance at a national level to reflect a relationship in the model.
- Countries without all the selected socio-economic variables.
- Eccentric values,when exceptional events or other factors would clearly show abnormal levels of victims, such as Hurricane Mitch in Nicaragua and Honduras or droughts in Sudan and Mozambique.

Transformation of socio-economic variables

For statistical analysis the socio-economic variables being tested had to be converted into 21-year averages and then transformed into a logarithm value. For some of the variables, the logarithm was computed directly. For those expressed as a percentage, a transformation was applied in order that all variables would range between -∞ and +∞. For others, no logarithmic transformation was needed. For instance, 'population growth' already behaves in a cumulative way and could be put directly into the calculation.

EQUATION 10 TRANSFORMATION FOR VARIABLES RANGING BETWEEN 0 AND 1

EQ10 $$V_i' = \frac{V_i}{(1 - V_i)}$$

Where

V_i' is the transformed variable (ranging from -∞ to +∞)

V_i is the socio-economic variable (ranging from 0 to 1)

Choice between variables

One important condition when computing regressions is that the variables included in the model should be independent, i.e. the correlation between two sets of variables is low. This is clearly not the case with HDI and GDPcap purchasing power parity (further referred to as GDPcap), which are highly correlated. GDPcap was used more than HDI because HDI was not available for several countries. In order to keep the sample as complete as possible, a choice between available variables was made choosing variable datasets that were as independent from each other as possible. This choice was performed by the use of both matrix-plot and correlation-matrix (using low correlation, hence low p-value, as the selection criteria).

The stepwise approach

For each type of hazard, numerous stepwise (back and forth steps) linear regressions were performed in order to identify significant socio-economic variables. The validation of each regression result was carried out using R2, variance analysis and detailed residual analysis.

Once the model was derived, the link between modelled estimated-killed and number-of-killed observed from EM-DAT was provided by both graph plots and computation of Pearson correlation coefficients.

If one can intuitively understand that physical exposure is positively related with the number of victims, and that GDPcap is inversely related with the number of victims (the lower the GDP, the higher the number of victims), this is less obvious for other variables such as the percentage of arable land. This method multiple logarithmic regression allows the estimation of the α_i coefficients.Their signs provided information to show if the variables were in a numerator or denominator position and hence the positive or inverse relationship between the variable and modelled deaths.

This model allowed the identification of parameters leading to higher/lower risk, but should not be used as a predictive model. Small differences in the logarithm scale can induce large ones in the modelled number of deaths.

The results following this method were surprisingly high and relevant, especially considering the independence of the data sources and the coarse resolution of the data at the global scale.

T.5.3 Mapping Risk

A judgement was made between the different risk indicators (i.e. killed, killed per million inhabitant, killed per population exposed).

T.5.4 Earthquake

Statistical model

The multiple regression was based on 48 countries. The best-fit regression line followed Equation 11 (see following page).

EQUATION 11 MULTIPLE LOGARITHMIC REGRESSION MODEL FOR EARTHQUAKES

EQ11 $$\ln(K) = 1.26\ln(PhExp) + 12.27 \cdot U_g - 16.22$$

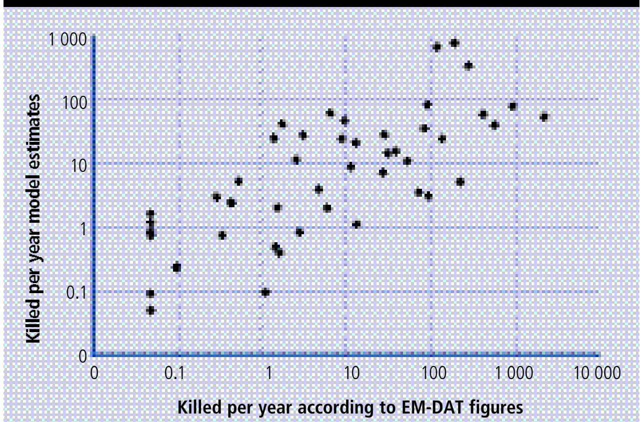
Where
K is the number of killed from earthquakes
PhExp is the physical exposure to earthquakes
U_g is the rate of urban growth (rates do not request transformation as it is already a cumulative value)

TABLE T.8 EXPONENT AND P-VALUE FOR EARTHQUAKE MULTIPLE REGRESSION

48 countries	B	p-value[h]
Intercept	−16.22	0.000000
PhExp	1.26	0.000000
U_g	12.27	0.047686

R= 0.75, R^2= 0.56, adjusted R^2= 0.54

FIGURE T.6 SCATTER PLOT OF THE OBSERVED NUMBER OF PEOPLE KILLED BY EARTHQUAKES (EM-DAT) AND THE MODEL PREDICTIONS



Source: The EM-DAT OFDA/CRED International Disaster Database and UNEP/GRID-Geneva

The variables retained by the regression include physical exposure and the rate of urban growth. Explained variance is smaller than for flood or cyclones (R^2=0.544), however considering the small length of time taken into account (21 years as compared to the long return period of earthquakes), the analysis delineates a reasonably good relation. Physical exposure is of similar relevance than for previous cases, relevant p-value. Urban growth is also highly negatively correlated with GDP and HDI. Thus, a similar correlation (but slightly inferior) could have been derived using HDI or GDP.

T.5.5 Tropical cyclone

Statistical model

The multiple regression was based on 32 countries and the best-fit regression line followed Equation 12.

The plot delineates a clear linear distribution of the data as seen in Figure T.7.

The parameters highlighted show that physical exposure, HDI and the percentage of arable land were associated with cyclone hazards.

The GDPcap is strongly correlated with the HDI or negatively with the percentage of urban growth. In most of the cases, the variable GDPcap could be replaced by HDI as explained previously. However, these results show with confidence that poor countries and countries with low human development index rank are more vulnerable to cyclones.

With a considerable part of variance explained by the regression (R^2 = 0.863) and a high degree of confidence in the selected variables (very small p-value) over a sample of 32 countries, the model achieved is solid.

In the model, the consequences of Hurricane Mitch could easily be depicted. Indeed, Honduras and Nicaragua were far off the regression line (significantly underestimated). This is explained by the high impact of Mitch compared to other hurricanes. The extreme values given by this event led to Honduras and Nicaragua being rejected from the model.

EQUATION 12 MULTIPLE LOGARITHMIC REGRESSION MODEL FOR TROPICAL CYCLONE

EQ12 $$\ln(K) = 0.63\ln(PhExp) + 0.66\ln(\overline{Pal}) - 2.03\ln(\overline{HDI}) - 15.86$$

Where
K is the number of killed from cyclones
PhExp is the physical exposure to cyclones
$\overline{Pal}$ is the transformed value of percentage of arable land
$\overline{HDI}$ is the transformed value of the Human Development Index

h. In broad terms, a p-value smaller than 0.05 shows the significance of the selected indicator, however this should not be used blindly.

TABLE T.9 EXPONENT AND P-VALUE FOR CYCLONES MULTIPLE REGRESSION

21 countries	B	p-value[i]
Intercept	−15.86	0.00000
ln(PhExp)	0.63	0.00000
$\ln(\overline{Pal})$	0.66	0.00013
$\ln(\overline{HDI})$	−2.03	0.00095

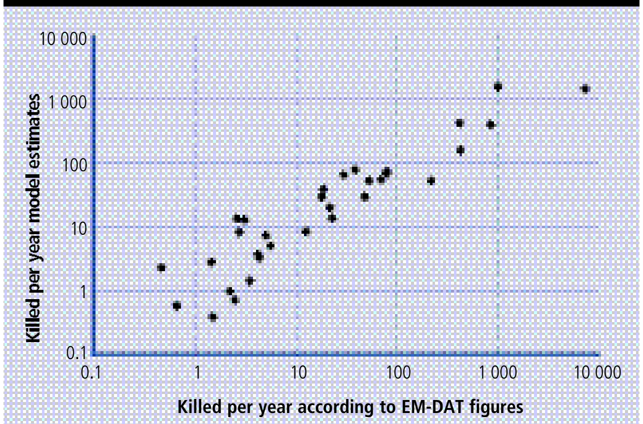
R= 0.93, R^2= 0.86, adjusted R^2= 0.85

TABLE T.10 EXPONENT AND P-VALUE FOR FLOOD INDICATORS

90 countries	B	p-value[i]
Intercept	−5.22	0.00000
ln(PhExp)	0.78	0.00000
$\ln(GDP_{cap})$	−0.45	0.00002
ln(Density)	−0.15	0.00321

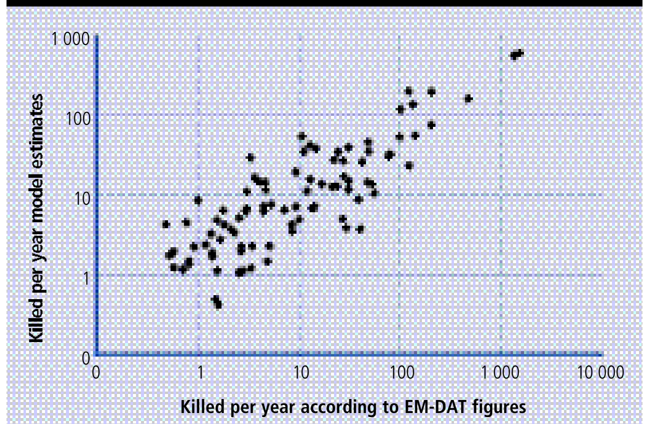
R= 0.84, R^2= 0.70, adjusted R^2= 0.69

FIGURE T.7 SCATTER PLOT OF THE OBSERVED NUMBER OF PEOPLE KILLED BY TROPICAL CYCLONE (EM-DAT) AND THE MODEL PREDICTIONS



Source: The EM-DAT OFDA/CRED International Disaster Database and UNEP/GRID-Geneva

FIGURE T.8 SCATTER PLOT OF THE OBSERVED NUMBER OF PEOPLE KILLED BY FLOOD (EM-DAT) AND THE MODEL PREDICTIONS



Source: The EM-DAT OFDA/CRED International Disaster Database and UNEP/GRID-Geneva

T.5.6 Flood

Statistical model

The multiple regression was based on 90 countries. The best-fit regression line followed Equation 13.

Due to space constraints, only a selection of countries was included in the above scatter plot. A comprehensive list of countries affected by floods is provided below:

Albania, Algeria, Angola, Argentina, Australia, Austria, Azerbaijan, Bangladesh, Benin, Bhutan, Bolivia, Botswana, Brazil, Burkina Faso, Burundi, Cambodia, Cameroon, Canada, Chad, Chile, China, Colombia, Costa Rica, Côte d'Ivoire, Czech Republic, Dominican Republic, Ecuador, Egypt, El Salvador, Ethiopia, Fiji, France, Gambia, Georgia, Germany, Ghana, Greece, Guatemala, Haiti, Honduras, India, Indonesia, Iran (Islamic Republic of), Israel, Italy, Jamaica, Japan, Jordan, Kenya, Lao People's Democratic Republic, Malawi, Malaysia, Mali, Mexico, Republic of Morocco, Mozambique, Nepal, Nicaragua, Niger, Nigeria, Pakistan, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Poland, Portugal, Republic of Korea, Republic of Moldova, Romania, Russian Federation, Rwanda, Saudi Arabia, Sierra

EQUATION 13 MULTIPLE LOGARITHMIC REGRESSION MODEL FOR FLOOD

EQ13 $$\ln(K) = 0.78\ln(PhExp) + 0.45\ln(GDP_{cap}) - 0.15\ln(D) - 5.22$$

Where
K is the number of killed from floods
PhExp is the physical exposure to floods
GDP_{cap} is the normalised Gross Domestic Product per capita (purchasing power parity)
D is the local population density (i.e. the population affected divided by the area affected)

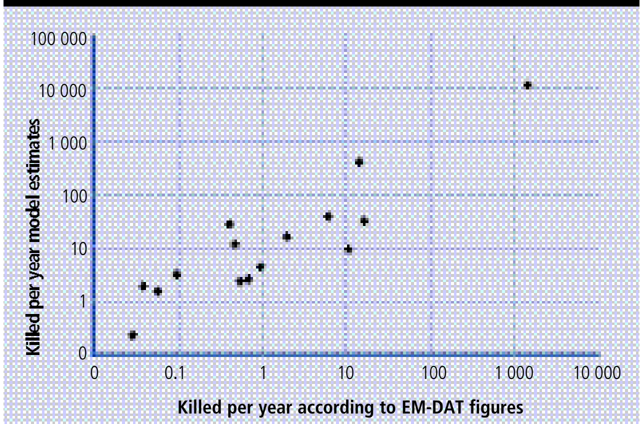
i. In broad terms, a p-value smaller than 0.05 shows the significance of the selected indicator, however this should not be used blindly.

TABLE T.11 EXPONENT AND P-VALUE FOR DROUGHT MULTIPLE REGRESSION

Predictor	Coef	SE Coef	T	p-value[j]
Constant	14,390	3,411	4.22	0.001
PhExp3_5	1.2622	0.2268	5.57	0.000
$WAT_{TOT}^{(1n)}$	-7,578	1,077	-7.03	0.000

S = 1,345, R-Sq = 0.812, R-Sq(adj) = 0.78

FIGURE T.9 SCATTER PLOT OF THE OBSERVED NUMBER OF PEOPLE KILLED BY DROUGHT (EM-DAT) AND THE MODEL PREDICTIONS



Source: The EM-DAT OFDA/CRED International Disaster Database and UNEP/GRID-Geneva

Leone, Slovakia, South Africa, Spain, Sri Lanka, Thailand, Tunisia, Turkey, Uganda, Ukraine, United Kingdom of Great Britain and Northern Ireland, United Republic of Tanzania, United States of America, Viet Nam, Yemen and Zimbabwe.

The variables selected by the statistical analysis are physical exposure, GDP_{cap} and local density of population. GDP_{cap} being highly correlated with HDI, this later could have been chosen as well. The GDP_{cap} was chosen due to slightly better correlation between the model and the observed killed, as well as because of lower p-value. Regression analysis supposes the introduction of non-correlated parameters, thus preventing the use of all these variables.

The part of explained variance (R^2 = 0.70) associated with significant p-value (between 10^{-23} and $2{\cdot}10^{-3}$) on 90 countries is confirming a solid confidence in the selection of the variables (see Table T. 10 on the previous page).

T.5.7 Drought

Statistical model

The regression analysis was performed using the six different exposure datasets derived from IRI drought maps. In general, the models were based on three-month thresholds to give better results. The dataset based on a drought threshold set at three months, at 50 percent below the median precipitation between 1979-2001, was finally selected as the exposure data.

The multiple regression was based on 15 countries. The best-fit regression line followed Equation 14.

Rejected countries: Swaziland and Somalia (WAT_{TOT} value inexistent), North Korea (reported WAT_{TOT} of 100 percent is highly doubtful), Sudan and Mozambique (eccentric values, suggesting other explanation for deaths).

The small p-values observed suggest a relevant selection of the indicators among the list of available datasets. It is to be noted that the high coefficient for WAT_{TOT} (−7.578) denotes a strong sensitivity to the quality of the data. This implies that even a change of 1 percent in total access to water would induce significant change in the results. This would be especially so for small values where small changes have bigger influence in proportion.

The model could not be used for predictive purposes. Inconsistencies were found in the data that require further verification.

EQUATION 14 MULTIPLE LOGARITHMIC REGRESSION MODEL FOR DROUGHT

EQ14 $$\ln(K) = 1.26\ln(PhExp3\_50) - 7.58\ln(WAT_{TOT}) + 14.4$$

Where
K is the number of killed from droughts
PhExp3_50 is the number of people exposed per year to droughts. A drought is defined as a period of at least three months less or equal to 50 percent of the average precipitation level (IRI, CIESIN/IFPRI/WRI)
WAT_{TOT} is the percentage of population with access to improved water supply (WHO/UNICEF)

j. In broad terms, a p-value smaller than 0.05 shows the significance of the selected indicator, however this should not be used blindly.

The variables associated with disaster risk through statistical analysis were physical exposure and the percentage of population with access to improved water supply. A strong correlation was established (R^2 = 0.81) indicating the solidity of the method as well as the reliability of these datasets for such a scale of analysis.

Figure T.9 shows the distribution (on a logarithmic scale) of expected deaths from drought and as predicted from the model. A clear regression can be drawn. It should be noted that if Ethiopia were to be excluded, the correlation would fall to (R^2 = 0.6). However, the offset and the slope of the regression line do not change significantly, reinforcing the robustness of the model.

As far as 1.26 is close to 1, the number of killed people grows proportionally to physical exposure. Also, the number of killed people decreases as a percentage of population when improved water supply grows. This latter variable should be seen as an indicator of the level of development of the country, as it was correlated to other development variables, such as the under-five mortality rate (Pearson correlation r = –0.64) and Human Development Index (r = 0.65).

Some countries with large physical exposure did not report any deaths to drought (United States of America, Viet Nam, Nigeria, Mexico, Bangladesh, Iran, Iraq, Colombia, Thailand, Sri Lanka, Jordan, Ecuador). This could be for a number of reasons. Either the vulnerability is null or extremely low, e.g. USA and Australia, or the number of reported killed from food insecurity is placed under conflict in EM-DAT, e.g. Iraq and Angola. For other countries, further inquiry might be necessary.

T.6 Multiple Risk Integration

So far, the precision and quality of the data as well as the sensitivity of the model do not allow the ranking of countries for disaster risk.

T.6.1 Methods

How to compare countries and disasters

A multiple-hazard risk model was made by adding expected deaths from each hazard type for every country. In order to reduce the number of countries with no data that would have to be excluded from the model, a value of 'no data' for countries without significant exposure was replaced by zero risk of deaths.

Countries were considered as not affected if the two following conditions were met: a physical exposure smaller than 2 percent of the national population AND an affected population smaller than 1,000 per year.

Some 39 countries were excluded from the analysis. Despite this, it is known that each was exposed to some level of hazard and 37 countries with recorded disaster deaths were in EM-DAT. This list of countries identifies places where improvement in data collection is needed to allow their integration in future work. Reasons that individual countries were excluded were: countries marginally affected by a specific hazard, countries affected but without data; and countries where the distribution of risk could not be explained by the model (for example, for drought in Sudan, where food insecurity and famine is more an outcome of armed conflict than of meteorological drought as defined in the model).

Once the countries to be included in the model were identified, a Boolean process was run to allocate one of five statistically defined categories of multi-hazard risk to each country. Figure T.10 illustrates the different steps taken to incorporate values into a multiple-risk index. Once this process had been completed, three different products were available:

- A table of values for the countries that include the data for relevant hazards or countries without data but marginally affected (210 countries).
- A list of countries with missing data (countries with reported deaths but without appropriate data).
- A list of countries where the model could not be applied (indicators do not capture the situation in these countries, case of countries not explained by the model, or rejected during the analysis because the indicators are not relevant to the situation).

Multiple risk computation

Multiple risk was computed using the succession of formulae as described in Equation 15 (see following page).

Between each addition, the whole process described in Figure T.10 (see following page) needed to be run in order to identify those countries where a value represented by zero needed, either to be replaced by a value calculated from the selected hazard model, or if not, the country was placed in the 'not-relevant' or 'no data' lists (see below).

EQUATION 15 COMPUTATION OF MULTIPLE RISK BY SUMMING CALCULATED DEATHS AS MODELLED FOR RISK FOR CYCLONE, FLOOD, EARTHQUAKE AND DROUGHT

EQ15

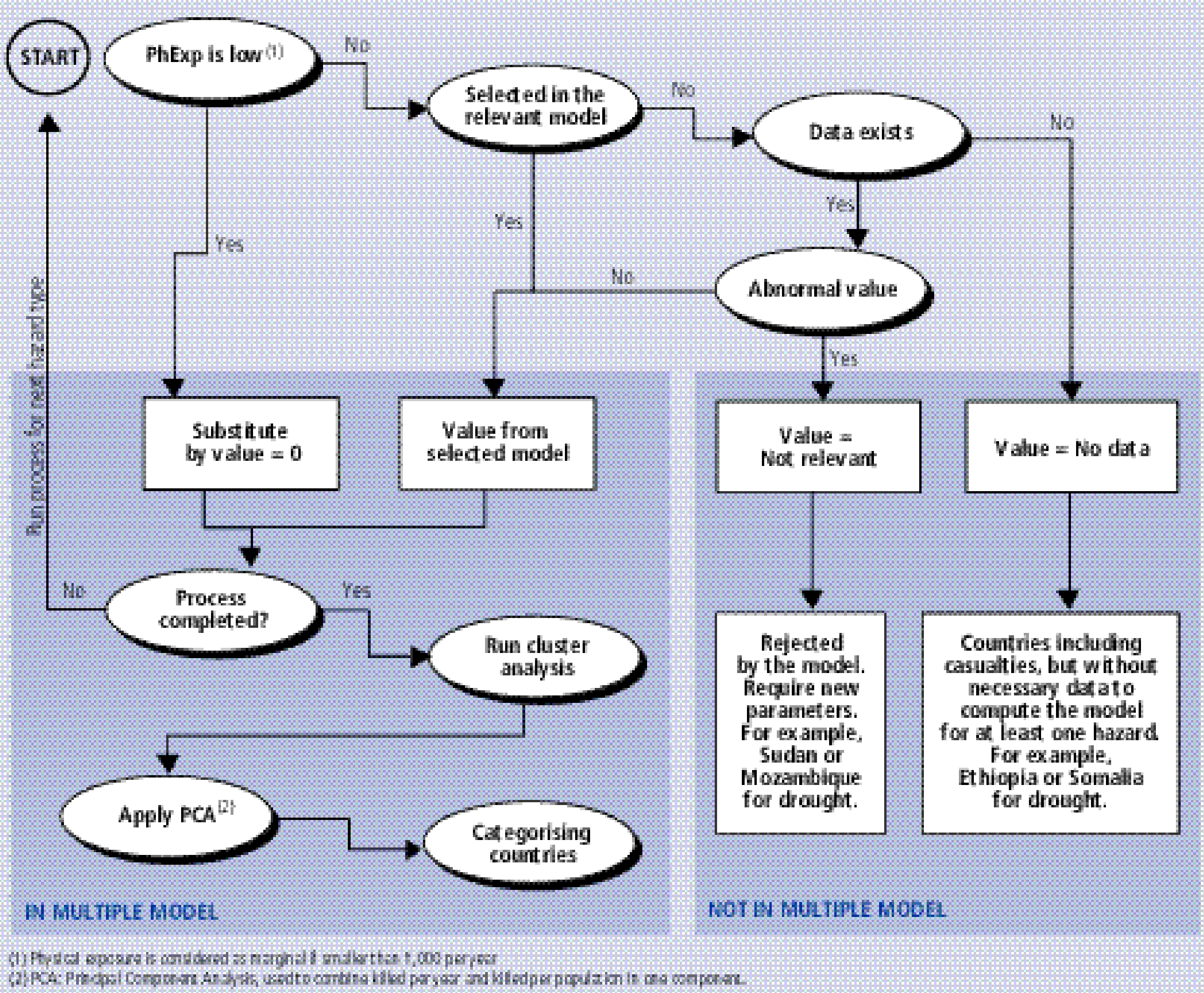
$$K_{cyclones}\left(PhExp_{cyclones}^{0.63}\cdot\overline{Pal}^{0.66}\cdot\overline{HDI}^{-2.03}\cdot e^{-15.86}\right)+K_{floods}\left(PhExp_{floods}^{0.78}\cdot GDP_{cap}^{-0.45}\cdot D^{-0.15}\cdot e^{-5.22}\right)+$$

$$K_{earthquakes}\left(PhExp_{earthquakes}^{1.26}\cdot U_{g}^{12.27}\cdot e^{-16.27}\right)+K_{droughts}\left(PhExp3\_50^{1.26}\cdot WAT_{TOT}^{-7.58}\cdot e^{14.4}\right)$$

Where

e	is the Euler constant (=2.718…)
PhExp	is the physical exposure of selected hazard
HDI	is the Human Development Index
GDP_{cap}	is the Gross Domestic Product per capita at purchasing power parity
D	is the local density (density of population in the flooded area)
U_g	is the Urban growth (computed over three-year period)
WAT_{TOT}	is the access to safe drinking water

FIGURE T.10 MULTIPLE RISK INTEGRATION



In order to examine the fit between model multi-hazard risk and recorded deaths, data from both sources were categorised into five country risk classes. A cluster analysis minimising the intra-class distance and maximising the inter-classes (K-means clustering method) was performed. This meant that a purely statistical process had been used to identify severities of risk from the model and deaths as recorded by EM-DAT.

In order to take both risk indicators (killed and killed per inhabitant) into account, a Principal Component Analysis (PCA) was performed to combine the two. Then a distinction was made between countries smaller than 30,000 km squared and with population density higher than 100 inhabitants per km squared.

T.6.2 Results

Modelled countries without reported deaths

The multi-hazard DRI was computed for 210 countries. This includes 14 countries where no recorded deaths were reported in the last two decades from EM-DAT: Barbados, Croatia, Eritrea, Gabon, Guyana, Iceland, Luxembourg, Namibia, Slovenia, Sweden, Syrian Arab Republic, The former Yugoslav Republic of Macedonia, Turkmenistan and Zambia.

No data, abnormal values and specific cases

Through the Principal Component Analysis transformation, inferior and superior thresholds were identified. This was performed on both observed and modelled deaths. For 14 countries, a value was calculated in the multi-hazard risk model even though no deaths had been recorded by EM-DAT in the 1980-2000 period. On the other hand, 37 countries where deaths were recorded could not be modelled, either because of a lack of data or because they did not fit with the model assumptions. These countries were:Afghanistan, Azerbaijan, Cuba, Democratic People's Republic of Korea, Democratic Republic of the Congo, Djibouti, Dominica, France, Greece, Liberia,Malaysia,Montserrat, Myanmar, New Caledonia, Portugal, Solomon Islands, Somalia, Spain, Sudan, Swaziland, Taiwan, Tajikistan, Vanuatu, Yugoslavia, Antigua and Barbuda, Armenia, Guadeloupe, Guam, Israel, Martinique, Micronesia (Federated States of), Netherlands Antilles, Puerto Rico, Reunion, Saint Kitts and Nevis, Saint Lucia, United States Virgin Islands.

Countries absent of both EM-DAT and Model

Two countries were absent from both EM-DAT and the model: Anguilla (a dependency of the United Kingdom) and Bosnia-Herzegovina.

EM-DAT-DRI multi-hazard risk comparison results

The results of the comparison of modelled and EM-DAT multi-hazard deaths are presented and discussed in Chapter 2. For more information, including country specific variables, researchers are encouraged to visit the Report website.

T.7 Technical Conclusions and Recommendations

T.7.1 The DRI – A work in progress

The DRI is a statistically robust tool

The results generated by the DRI method were statistically robust with a high level of confidence. This is especially the case considering the independence of the data sources and the coarse resolution of the data available at the global scale. The statistically strong links — both between observed and modeled deaths and between socio-economic variables associated with human vulnerability and levels of risk — that were found in the DRI study are not often found in similar studies that analyse geophysical datasets and socio-economic data. The model has succeeded in opening the great potential for future national level disaster risk assessments. It provides the first, solid statistical base for understanding and comparing countries' disaster risk and human vulnerability.

The DRI is not a predictive model

This is partly a function of a lack of precision in the available data. But it also shows the influence of local context.The risk maps provided in this research allow a comparison of relative risk between countries, but cannot be used to depict actual risk for any one country. Sub-national risk analysis would be required to inform development and land-use planning at the national level.

How to link extreme and everyday risk?

Extraordinary events by their very nature do not follow the normal trend. Hurricane Mitch in 1998, the rains causing landslides in Venezuela in 1999 or the 1988 earthquake in Armenia were off the regression line. This is due to the abnormal intensity of such events. These events are (hopefully) too rare to be usefully included in a two-decade period of study. Incorporating this level of intensity can only be done on an event-per-event approach.

T.7.2 Ways forward

Socio-economic variables

Results showed that global datasets can still be improved both in terms of precision and completeness. However, they already allow the comparison of countries. Other indicators — such as a corruption, armed conflict or political events — would be interesting to test in the model in the future.

Floods

Geophysical data can be improved. The watersheds used to estimate flood physical exposure were based on a 1 km cell resolution for elevation. A new global dataset on elevation from radar measures taken from a National Aeronautics and Space Administration (NASA) space shuttle is expected in 2004. It consists of a 30m resolution grid for the USA and 90m resolution for global coverage. This dataset will allow the refining of estimated areas exposed to flood risk. This advance will be especially welcome for the central Asian countries, where the quality of globally accessible available data was low.

Earthquakes

If information on soil (i.e. Quaternary rocks) and fault orientations can be generated, it would be possible to compute intensity using a modified Mercali scale, with much higher precision for delineating the affected area. Alternatively, a method for deriving frequency based on the Global Seismic Hazard Map from the GSHAP[13] could be used.

Cyclones

Once data from the North Indian Ocean is available, a vector approach should be applied using the PreView Global Cyclone Asymmetric Windspeed Profile model developed by UNEP/GRID-Geneva. This method computes areas affected, based on central pressure and sustainable winds.

Drought

Other precipitation datasets with higher spatial resolution could be usefully tested. The use of geo-climatic zones might be useful in order to take into account the usual climate of a specific area. Indeed, a drop of 50 percent precipitation might not have the same consequence on a humid climate as on a semi-arid area.The use ofthe Global Humidity Index (from UNEP/GRID UEA/CRU) might help in differentiating these zones. Measuring food insecurity (by using information on conflict and political status) would be also a significant improvement as compared to meteorological drought. Alternatively, drought could be measured in terms of crop failure through use of satellite imagery. This will be closer to drought as it impacts on food security.

The case of small islands and archipelagos

In some cases, small islands and archipelagos were too small to be considered by the GIS-automated algorithms. This was typically the case for population data. The raster information layer for population could not be used to extract the population of small islands. For single island countries,the problem might be overcome by using the population of the country, but for others this was not possible. Indeed, when superimposing cyclone tracks on top of archipelagos, the population is needed for each island. A manual correction is needed, but could not be performed due to the time-frame of the study. The compilation of socio-economic variables was also not complete for the islands. This might be improved by collaborating with agencies such as the South Pacific Applied Geoscience Commission (SOPAC) and Economic Commission for Latin America and the Caribbean (ECLAC) as both agencies are currently working on indicators for island vulnerability.

For all these reasons,the case of small island states and archipelagos would need a separate study.

Death as an indicator for risk

To what extend are deaths proportional to the significance of total losses, including losses of livelihood? In the case of earthquakes, where no early warning exists, this might be a good proxy. But it will depend on whether the earthquake epicentre is located in a rural or urban area. For tropical cyclone and flood, deaths are usually much smaller in relation to losses of houses, infrastructures and crops. In drought, the relationship is even more exaggerated. A much higher number of people are affected through the slow erosion of rural livelihoods and the possible influence of intervening factors, such as armed conflict, economic or political crisis, or epidemic disease such as HIV/AIDS. This makes separating the impact of drought from other factors a big challenge.

The ideal would be to have access to records of livelihood losses in order to calibrate the severity of one hazard type as compared to another (while considering the magnitude of a hazard). Other approaches for obtaining a structured assessment of comparative risk by country could include an assessment on the comparative severity of hazard using local and expert knowledge, or using relief and aid organisation budget data as a proxy for risk severity.

Extending to other hazards

Volcanic eruptions. The variability of volcanic hazards was too complex to be entered into a general model. Volcanic hazard ranges from lahars linked with precipitation level, seismicity, topography and soils characteristics, to tephra falls influenced by the prevailing wind direction and strength, and phreatomagmatic eruption. Despite this complexity, much data is available for volcanic hazard and each active volcano is well described. Data needed for a global assessment of volcanic risk probably exists. But a finer resolution for elevation is needed. It would be necessary to include data on the shape and relief of volcanoes, computing slopes and hazard from lahars. Remote sensing analysis for local assessment of danger and population distribution would also be required.

Tsunamis and landslides. Some countries are not well represented by the model because they are affected by hazards that are not of global significance. This is the case of Papua New Guinea and Ecuador, both affected by tsunamis, respectively 67.8 percent and 14.3 percent of national deaths. Landslides also cause significant losses in Indonesia (13 percent), Peru (33 percent) and Ecuador (10 percent) of recorded disaster-related deaths. As a result, the multi-hazard DRI is under evaluated for these countries.

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1. Burton et al. 1993, p.34.
2. Coburn et al. 1991, p. 49.
3. Guha-Sapir, Debatathi and Below, Regina (2002) "Quality and Accuracy of Disaster Data: A Comparative Study of 3 Global Datasets," WHO Centre for Research on the Epidemiology of Disasters, University of Louvain School of Medicine for the Disaster Management Facility of the World Bank, Brussels.
4. Idem, p.14.
5. For a more detailed argument see the CRED-EM-DAT database http://www.cred.be/ and IFRC World Disaster Reports.
6. UNEP, 2002.
7. Birdwell & Daniel, 1991.
8. Bolt et al. 1975.
9. Bolt et al. 1975.
10. Birdwell & Daniel, 1991.
11. Landsea, 2000.
12. Giardini, 1999.

BIBLIOGRAPHY

Adger, W.N.1999. Social Vulnerability to Climate Change and Extremes in Coastal Vietnam. *World Development* 27: 249-69.

_________. Institutional Adaptation to Environmental Risk Under the Transition in Vietnam. *Annuls of the Association of American Geographers* 90: 738-758.

Alexander, D. 1993. *Natural Disasters.* London: UCL Press.

_________. 2000. *Confronting Catastrophe: New Perspectives on Natural Disasters,* New York: Oxford University Press.

Albala-Bertrand, J.M. 1993. *Political economy of large natural disasters:with special reference to developing countries,* Oxford: Clarendon Press.

Allen, E. 1994. Political Responses to Flood Disaster: The Case of Rio De Janeiro, 1988. In A. Varley (Ed.) *Disasters, Development and the Environment.* London: Belhaven.

Amjad Bhatti, Madhavi Malalgoda Ariyabandu. 2002. *Disaster Communication: A Resource Kit for the Media*. Colombo, Sri Lanka: Duryog Nivaran.

Anderson, M. 1990. Which Costs More: Prevention or Recovery? In A. Kreimer and M. Munasinghe (Eds.) *Managing Natural Disasters and the Environment:* 17-27. Washington, DC: World Bank.

Anderson, M. and Woodrow, P. 1989. *Rising from the Ashes: Development Strategies in Times of Disaster.* Boulder, CO: Westview (reprinted, 1999, by IT Publications, London).

Ariyabandu, M. 1999. *Defeating Disasters: Ideas for Action.* Colombo, Sri Lanka: Duryog Nivaran and Intermediate Technology Development Group.

Bankoff, G. 2001. Rendering the World Safe: Vulnerability as Western Discourse. *Disasters* 25 (10): 19-35.

Barnett, A. and Whiteside, A. 2001. *AIDS in the Twenty-First Century: Disease and Globalization.* Basingstoke, U.K.: Palgrave/Macmillan.

Baas, S., Batjargal, E. and Swift, J. 2001. From Wisner, B., 2002, background paper, invited contribution.

Bebbington, A. and Perrault, T. 1999. Social Capital and Political Ecological Change in Highland Ecuador: Resource Access and Livelihoods. *Economic Geography* 75 (4): 395-419.

Benjamin, S. 2000.Governance, economic settings and poverty in Bangalore. *Environment and Urbanisation* 12 (1): 35-56.

Benson, C.2003. Macroeconomic Concepts of Vulnerability: Dynamics, Complexity and Public Policy. In Bankoff, G., Frerks, G. and Hilhorst, T. (Eds.) *Vulnerability: Disasters, Development and People.* London: Earthscan.

Benson, C. and Clay, E. 1998. *The Impact of Drought on Sub-Saharan African Economies,* World Bank Technical Paper No. 401. Washington, DC: World Bank.

Berke, P., Kartez, J. and Wenger, D. 1993. Recovery after Disaster: Achieving Sustainable Development, Mitigation and Equity. *Disasters* 17 (2): 93-109.

Birdwell, K.R. and Daniels, R.C. 1991. A Storm Climatology Database with Applications in Regional and Global Change Studies. *Bulletin of the American Meteorological Society,* Vol. 72, No. 7.

Black, R. 1998. *Refugees, Environment and Development.* Harlow. Essex: Longman.

Blaikie, P.M. and Brookfield, H.C. 1987. *Land Degradation and Society.* London: Methuen.

_________ and Cannon, T., Davis, I. and Wisner, B. 1994. *At Risk: Natural Hazards, People's Vulnerability, and Disasters.* London: Routledge.

Bosnia and Herzegovina, Council of Ministers, Law on Ministries and Other Bodies of Administration of Bosnia and Herzegovina, Sarajevo, January 2003.

Brosnam, D. 2000. *The Montserrat Volcano: Sustainable Development in Montserrat.* Portland, OR: Sustainable Ecosystems Institute. www.sei.org/sustainable_development.html

Brown, H. A. 1994. Economics of disasters with special reference to the Jamaican Experience. Working paper 2, Jamaica: Centre for Environment and Development, University of the West Indies.

Bull-Kamanga, Liseli et al.2003. From Everyday Hazards to Disasters, the Accumulation of Risk in Urban Areas. *Environment and Urbanisation,* Vol 15 No 1. April 2003. London: IIED.

Caballeros, R. y R. Zapata. 1999. *América Latina: el impacto de los desastres naturales en el desarrollo, 1972-1999.* México, CEPAL.

Cannon, T. 1994. Vulnerability Analysis and the Explanation of 'Natural' Disasters. In Varley, A. (Ed.) *Disasters, Development and the Environment:* 13-30. London: Belhaven Press.

_________. 2000. Vulnerability Analysis and Disasters. In Parker, D. (Ed.) *Floods:* 43-55. London: Routledge.

_________. 2002. Gender and Climate Hazards in Bangladesh. In Masika, R. (Ed.) *Gender, Development and Climate Change:* 45-50. Oxford: Oxfam.

_________ and Twigg, J., Rowell, J. 2003. *Social Vulnerability, Sustainable Livelihoods and Disasters.* London: DFID.

Cardona, O.D. 2003. The need for rethinking the concepts of vulnerability and risk from a holistic perspective: a necessary review and criticism for effective risk management. In Bankoff, G., Frerks, G, and Hilhorst D. (Eds.) *Mapping Vulnerability: Disasters, Development and People.* London: Earthscan.

Cardona, O.D., Yamín, L.E., Arámbula, S. and Molina, L.F. 2002. Retención y Transferencia del Riesgo Sísmico en Colombia: Evaluación Preliminar de una Posible Estrategia Financiera y del Mercado Potencial, Universidad de los Andes, CEDERI, Departamento Nacional de Planeación de Colombia – World Bank.

Castells, M. 1996. *The Information Age: Economy, Society and Culture Volume 1, The Rise of the Network Society.* Oxford: Blackwell Publishers.

Challenger, B. 2002. Linking adaptation to climate change and disaster mitigation in the Eastern Caribbean:experiences and opportunities. Paper presented at the UNEP Expert Group Meeting on Integrating Disaster Reduction and Adaptation to Climate Change. Havana, Cuba.

Chambers, R. 1989. Editorial Introduction: Vulnerability, Coping and Policy. *IDS Bulletin* 20 (2): 1-7.

Colletta, N.J., Cullen, M.L. 2000. *Violent Conflict and Transformation of Social Capital: Lessons from Cambodia, Rwanda, Guatemala and Somalia.* Washington DC: World Bank.

Comfort,L., Wisner, B., Cutter, S., Pulwarty, R.,Hewitt, K., Oliver-Smith, A., Weiner, J., Fordham, M., Peacock, W. and Krimgold, F. 1999. Reframing Disaster Policy: The Global Evolution of Vulnerable Communities. *Environmental Hazards* 1 (1): 39-44.

Cuny, F. and Hill, R. 1999. *Famine, Conflict and Response: A Basic Guide*. West Hartford, CT: Kumarian Press.

de Haan,Arjan.2000. Migrants.Livelihoods and rights:the relevance of migration in development policies, DFID Social Development Working Paper number 4.

de Waal, A. 2000. Democratic Political Process and the Fight against Famine. IDS Working Paper No. 107. Brighton: Institute of Development Studies.

DEC (Disasters Emergency Committee) 2001. Independent Evaluation of expenditure of DEC India Earthquake Appeal Funds January 2001-October 2001. London: DEC.

_________. 2002.The Gujarat Earthquake: Monitoring Visit Report to DEC. www.dec.org.uk

Devereux, S. 2001. Famine in Africa. In S. Devereux and S. Maxwell (Eds.) *Food Security in Sub-Saharan Africa,* ch. 5. London: ITDG Publishing.

DFID Bangladesh. 2003. Poverty, Disasters and the Environment in Bangladesh: A Quantitative and Qualitative Assessment of Causal Linkages. Paper prepared by C. Kelly and M.H. Khan Chowdhury with the collaboration of Concern, Disaster Forum and Helen Keller International Bangladesh, December 2003 for DFID, U.K.

Dovers, S. and Handmer, J. 1993. Contradictions in Sustainability. *Environmental Conservation* 20: 217-22.

Drèze, J. and Sen, A. 1989. *Hunger and Public Policy.* Oxford: Clarendon Press.

Emel, J. and Peet, R. 1989.Resource Management and Natural Hazards. In Peet, R. and Thrift,N. (Eds.) *New Models in Geography.* Vol. 1: 49-76. London: Unwin Hyman.

EM-DAT: The OFDA/CRED International Disaster Database, Université Catholique de Louvain,Brussels,Belgium. www.cred.be/emdat

Enarson, E. 2001. *We Want Work: Rural Women in the Gujarat Drought and Earthquake*. http://online.northumbria.ac.uk/geography_research/radix/resources/surendranagar.doc

Enarson, E. and Morrow, B. (Eds.) 1997. *Gendered Terrains of Disaster:Through Women's Eyes.* New York: Praeger.

Escobar, A. 1995. *Encountering Development: The Making and Unmaking of the Third World.* Princeton: Princeton University Press.

FAO (Food and Agriculture Organisation) 1999. Adverse effect of the drought on domestic food production during 1998/1999 in Iraq. www.casi.org.uk/info/fao_dr.html

Fernandez, Maria Augusta. 1999. *Cities at Risk: Environmental Degradation, Urban Risk and Disasters.* Quito, Ecuador: LA RED/USAID.

Fernando, Priyanthi and Fernando, Vijitha. 1997. *South Asian Women: Facing Disasters, Securing Life.* Colombo, Sri Lanka: Duryog Nivaran.

Fordham, M. 2003. Gender, Development and Disaster: The Necessity for Integration. In Pelling, M. (Ed.) *Natural Disasters and Development in a Globalizing World:* 57-74. London: Routledge.

Fothergill,A. 1996. Gender, Risk and Disaster. *International Journal of Mass Emergencies and Disasters* 14 (1): 33-56.

Frances, C. and Hanlon, J. 2001. *Mozambique and the Great Flood of 2000.* Oxford: Indiana and James Currey.

Francois, Jean and Rufin, Jean-Christophe. 1996. *Economie des guerres civiles.* Paris: Hachette.

Freeman, P., Martin, L., Mechler, R. and Warner, K. 2002. Catastrophes and Development: Integrating Natural Catastrophes into Development Planning. Disaster Risk Management Working Paper 4. Disaster Management Facility. Washington, DC: The World Bank www.worldbank.org/dmf/files/catastrophes_complete.pdf

Gass, V. 2002. *Democratizing Development: Lessons from Hurricane Mitch Reconstruction.* Washington, DC: Washington Office on Latin America (WOLA).

Gaye M. and Diallo, F. 1997. Community participation in the management of the urban environment in Rufisque, Senegal. *Environment and Urbanisation* 9 (1) 9-29.

Gibson, J.L. 1998. Social Networks and Civil Society in Processes of Democratisation. *Studies in Public Policy* No. 301, Centre for the Study of Public Policy (CSPP), University of Strathclyde, Glasgow.

Gilbert, R. and Kreimer, A. 1999. Learning from the World Bank's Experience of Natural Disaster Related Assistance. Disaster Management Facility, Working Paper Series 2. Washington, DC: The World Bank. www.worldbank.org/dmf/files/learningfromwb.pdf

Glantz, M. 2001. *Once Burned, Twice Shy? Lessons Learned from the 1997-98 El Niño.* Tokyo: United Nations University Press.

Goodhand, J., Hulme, D. and Lewer, N. 2000. Social capital and the political economy of violence: a case study of Sri Lanka. *Disasters* 24 (4) 390-406.

Government of Algeria. 2003. Bilan officiel du gouvernement après le seisme 21 mai 2003, Ministere del Interireur et des Collectivite Locales, in El Moudjahid.

Government of Haiti. 2003. Rapport de suivi du Plan National de Gestion de Risques et de Disastres, mimeo.

_________.2001.Enquete Budget-Consommation des Menages (EBCM 1999-2000) Volume II (Institut Haitien des Statistique et d'Informatique). www.ht.undp.org/pnud-hai/projets/Bestpract.htm

Haas, E., Kates, R. and Bowden, M. 1977. *Reconstruction Following Disaster.* Cambridge, MA: MIT Press.

Hamza, M. and Zetter, R. 1998. Structural adjustment, urban systems and disaster vulnerability in developing countries. *Cities* 15 (4): 291-299.

Hardoy, J.E., Mitlin, D. and Satterthwaite, D. 2001. E*nvironmental problems in an urbanizing world.* London: Earthscan.

Haq, K. and Kirdar, U. (Eds.) 1987. *Human Development, Adjustment and Growth.* Islamabad: North South Roundtable.

Heijmans, A. and Victoria, L. 2001. *Citizen-Based and Development-Oriented Disaster Response.* Quezon City, Philippines: Center for Disaster Preparedness. cdp@info.com.ph

Hewitt, K. (Ed.) 1983. *Interpretations of Calamity.* Boston: Allen and Unwin.

_________. 1995. Sustainable Disasters? Perspectives and Powers in the Discourse of Calamity, in Crush, J. (Ed.) *Power of Development* 115-28. London: Routledge.

_________. 1997 *Regions of Risk: A Geographical Introduction to Disasters.* Harlow: Longman.

_________. 1998. Excluded Perspectives in the Social Conception of Disaster. In Quarantelli, E. (Ed.) *What is a Disaster:* 75-91. London: Routledge.

Hill, A. and Cutter, S. 2001. Methods for Determining Disaster Proneness. In Cutter, S. (Ed.) *American Hazardscapes: The Regionalization of Hazards and Disasters,* Washington, DC: Joseph Henry Press.

Holloway, A. 2003. Background paper, invited contribution for *Reducing Disaster Risk.*

Hossain, Hameeda, Dodge, Cole P. and Abed, F.H. 1992. *From Crisis to Development: Coping with Disasters in Bangladesh.* Dhaka, Bangladesh: University Press.

Houghton, J. et al.(Eds.) 2001. *Climate Change 2001: The Scientific Basis.* Cambridge: Cambridge University Press.

IASC (Inter-Agency Standing Committee) 2002. *Growing the Sheltering Tree: Protecting Human Rights through Humanitarian Action.*

IDNDR (International Decade for Natural Disaster Reduction) 1999. Proceedings: Programme Forum. Geneva: IDNDR.

IFRC (International Federation of Red Cross and Red Crescent Societies) 1998. World Disasters Report 1998. Geneva: IFRC.

_________. 1999. *Vulnerability and Capacity Assessment: An International Federation Guide.* Geneva: IFRC.

_________. 1999. *World Disasters Report 1999.* Geneva: IFRC.

_________. 2000. *World Disasters Report 2000.* Geneva: IFRC.

_________. 2001. *World Disasters Report 2001.* Geneva: IFRC.

_________. 2002. *World Disasters Report 2002: Focus on Reducing Risk.* Geneva: IFRC.

_________. 2003. *World Disasters Report 2003.* Geneva: IFRC.

IISD (International Institute for Sustainable Development), IUCN (World Conservation Union) and SEI (Stockholm Environment Institute) 2003. Livelihoods and Climate Change: Combining Disaster Risk Reduction, Natural Resource Management and Climate Change. A conceptual paper prepared by the Task Force on Climate Change, Vulnerable Communities and Adaptation. Winnipeg, Canada: IISD

IPCC (Intergovernmental Panel on Climate Change) 2001. Climate Change: impacts, adaptation and vulnerability, summary for policy makers and technical summary for Working Group II Report. Geneva: IPCC.

ISDR (United Nations International Strategy for Disaster Reduction) 2001. Report of Working Group 3 to the ISDR Inter Agency Task Force for Disaster Reduction 2001.

_________. 2002. *Living with Risk: A Global Review of Disaster Reduction Initiatives.* Preliminary edition.Geneva:ISDR.

ISDR (United Nations International Strategy for Disaster Reduction)/RADIUS. 2001. *United Nations Initiative Towards Earthquake Safe Cities.* Geneva: ISDR.

Jabry, A. 2003. *Children in Disasters.* London: PLAN International. www.plan-uk.org/action/childrenindisasters

Johnson, L.T. 2003. Housing, sanitation and drinking water: strengthening lives and livelihoods, in Palakudiyil, T. and Todd, M. (Eds.) *Facing up to the Strom: How communities can cope with disaster:Lessons from Orissa and Gujarat.* London: Christian Aid.

Kasperson, R. and Kasperson, J. (Eds.) 2000. Global Environmental Risk. London: Earthscan.

Kelman, I. 2003. Beyond Disaster, Beyond Diplomacy. In Pelling, M. (Ed.) *Natural Disasters and Development in a Globalizing World:* 110-123. London: Routledge.

Khondker, H.H. 1992. Floods and Politics in Bangladesh. *Natural Hazards Observer* 16 (4): 4-6.

Kirby, A. (Ed.) 1990. *Nothing to Fear: Risks and Hazards in American Life.* Tucson: University of Arizona Press.

Kreimer, A.and Munasinghe, M. (Eds.) 1991. *Managing Natural Disasters and the Environment.* Washington, DC: World Bank.

Kropac, Michael. 2002. *Urban Development and Disaster Mitigation: DMI's Bhuj Reconstruction Project.* Ahmedabad, India: Disaster Mitigation Institute.

Krüger, Fred. 1999. Drought Hazards and Threatened Livelihoods - Environmental Perceptions in Botswana. In Lohnert, B. and Geist, H. (Eds.) *Coping with Changing Environments:* 175-190.

La Red. 1998. *Revista Desastres y Sociedad 9. Especial El Niño.* Lima: La Red. www.desenred ando.org/public/revistas/dys/rdys09/index.html

Lavell, Allan 1994. Prevention and Mitigation of Disasters in Central America: Vulnerability to disasters at the local level. In Varley, A. (Ed.) *Disasters, Development and Environment:* 49-63. Chichester, UK: Wiley.

Lavell, Allan (Ed.) 1994. *Viviendo en Riesgo: Comunidades Vulnerables y Prevencion de Desastres en America Latina.* Bogota, Colombia: CEPREDENAC/ FLACSO/ La Red.

Lavell,Allan and Franco, Eduardo. 1996. *Estado,Sociedad y Gestion de los Desastres en America Latina :En Busqueda del Paradigma Perdida.* Bogota, Colombia: La Red/ FLACSO.

Lewis, J. 1984. A Multi-Hazard History of Antigua. *Disasters* 8 (3): 190-7.

_________. 1990. The Vulnerability of Small Island-States to Sea Level Rise: the Need for Holistic Strategies. *Disasters,* 14 (3): 241-248.

_________. 1999. *Development in Disaster-prone Places.* London: IT Books.

Lungo, Mario and Baires, Sonia.1996. *De Terremotos, Derrumbes e Inundados : Los Riesgos Ambientales y el Desarrollo Urbano Sostenible en El Salvador.* San Salvador: FUNDE/La Red.

McIntire, J. 1987. Would Better Information From an Early Warning System Improve African Food Security? In Wilhite, D. and Easterling, W. (Eds.) *Planning for Drought:* 283-93. Boulder, CO: Westview.

Macrae, J. and Zwi, A. (Eds.) 1994. *War and Hunger: Rethinking International Responses to Complex Emergencies.* London: Zed Press.

Madeley, J. 1999. *Big Business, Poor Peoples: the Impact of Transnational Corporations on the World.* London: Zed Books.

Maskrey, A. 1989. *Disaster Mitigation: A Community Based Approach.* Development Guidelines No.3 Oxford: Oxfam.

_________. 1996. *Terremotos en el Tropico Humedo: la Gestion de los Desastres del Alto Mayo, Peru (1990- 1991), Limon,Costa Rica (1991) y Atrato Medio, Colombia (1992).* Bogota, Colombia: La Red.

_________. 1998. *Navegando entre Brumas: La Aplicacion de los Sistemas de Informacion Geografica al Analisis de Riesgo en America Latina.* Bogota, Colombia: La Red.

_________. 1999. Reducing Global Disasters. In: J. Ingelton (Ed.) *Natural Disaster Management:* 84-6. Leicester: Tudor Rose.

Maskrey, A. and Romero, Gilberto. 1986. *Urbanizacion y Vulnerabilidad Sismica en Lima Metropolitana.* Lima, Peru: PREDES.

McGranahan, G., Jacobi, P., Songsore, J., Surjadi, C. and Kjellén, M. 2001. *The Citizens at Risk: From Urban Sanitation to Sustainable Cities.* London: Earthscan.

Middleton,N. and O'Keefe, P. 1998. *Disasters and Development: The Politics of Humanitarian Aid.* London: Pluto Press.

Mitchell, J. (Ed.) 1999. *Crucibles of Hazard: Mega-Cities and Disasters in Transition.* Tokyo: United Nations University Press.

Nomdo, Christina and Coetzee, Erika. 2002. *Urban Vulnerability: Perspectives from Southern Africa.* Capetown, South Africa: PeriPeri Publications.

Moser, C. 1998. The asset vulnerability framework: re-assessing ultra poverty reduction strategies. *World Development* 26 (1): 1-19.

Munich RE. 2002. *Topics: Annual Review, Natural Catastrophes 2002.* Munich, Germany.

Narayan, D. and Petesch, P. (Eds.) 2002. *Voices of the Poor.* New York: Oxford University Press/World Bank.

ODI (Overseas Development Insititute) 2002. *Understanding Livelihoods in Rural India: Diversity, Change and Exclusion.* Personal communication, Status report on Orissa disaster mitigation programme. Indian Red Cross Society 2001.

OECD (Organisation for Economic Cooperation and Development)/Development Assistance Committee. 2002. Development Cooperation Report.

OECD and UNDP (United Nations Development Programme). 2002. *Sustainable Development Strategies A Resource Handbook.* Compiled by Barry Dalal-Clayton and Stephen Bass of the International Institute for Environment and Development. Earthscan Publications Ltd.

OECS (Organisation of Eastern Caribbean States). *Human Development Report 2002.* The OESC Secretariat.

Oliver-Smith, A. 1999. Peru's Five Hundred-Year Earthquake: Vulnerability in Historical Context. In Oliver-Smith, A. and Hoffman, S. (Eds.) *The Angry Earth:* 74-88. New York: Routledge.

Özerdem,A.2003. Disaster as Manifestation of Unresolved Development Challenges: The Marmara Earthquake in Turkey. In Pelling, M., (Ed.) *Natural Disasters and Development in a Globalising World.* London: Routledge.

Pacific Islands Development Program n.d. Agricultural Development and Disaster Preparedness. Honolulu: East-West Center.

PAHO (Pan American Health Organization). 1982. *Epidemiologic Surveillance after Natural Disaster.* Washington, DC: Pan American Health Organization.

_________. 1994. Empowering Local Communities to Reduce the Effects of Disasters. *Disasters: Preparedness in the Americas* 60 (October): 1, 7.

_________. 2000. *Natural Disasters: Protecting the Public's Health.* Washington, DC: PAHO.

Parker, D. (Ed.) 2000. *Floods.* 2 vols., London: Routledge.

Pelling, M. 1999. Participation, Social Capital and Vulnerability to Urban Flooding in Guyana. *International Journal of Development* 10: 469-486.

_________. 2002. Assessing Urban Vulnerability and Social Adaptation to Risk: A Case Study from Santo Domingo. *International Development Planning Review* 24 (1) 59-76.

_________. 2003a. (Ed.) *Natural Disasters and Development in a Globalizing World.* London: Routledge.

_________. 2003b. *The Vulnerability of Cities: Natural Disasters and Social Resilience*. London: Earthscan.

Pelling, M., Özerdem A. and Barakat, S. 2002.The Macro-economic Impact of Disasters, *Progress in Development Studies* 2 (4).

Pelling, M. and Uitto, J. 2002. Small Island Developing States: Natural Disaster Vulnerability and Global Change. *Environmental Hazards* 3: 49-62.

Peri Peri (Ed.) 1999. *Risk, Sustainable Development and Disasters: Southern Perspectives. Cape Town, South Africa: Peri* Peri Publications/Disaster Mitigation for Sustainable Livelihoods, Department of Environmental and Geographical Sciences, University of Cape Town.

Plan Puebla-Panama. 2003. Iniciativa Mesoamericana de Prevencion y Mitigacion de Desastres, 2003. Document Estrategico. Mineo.

ReliefWeb. 2002. UN declares 6 November: International Day for preventing the exploitation of the environment in war and armed conflict. UNEP 5, November 2002.

Republique d'Haiti, Ministere de l'economie et des finances. 2001. *Enquête Budget-Consommation des menages* (EBCM 1999-2000). Volume: II. Revenue. Depenses et consommation des menages.

Roy, B.C., Mruthyunjaya and Selvarajan, S. 2002. Vulnerability to Induced Natural Disasters with Special Emphasis on coping Strategies of the Rural Poor in Coastal Orissa, India. Paper prepared by the UNFCC COP8 Conference, October-November 2002.

Sachs, Jeffrey et al. 2001. Macroeconomics and Health: Investing in Health for Economic Development. Report of the Commission on Macroeconomics and Health to the Director-General of the World Health Organization. 20 December 2001.

Salazar, A. 2002. *Normal Life after Disasters? 8 Years of Housing Lessons, from Marathwada to Gujarat, Architecture + Design.* New Delhi. Jan/Feb.

Sanderson, D. 2000. Cities, Disasters and Livelihoods. *Environment and Urbanization* 12 (2): 93-102.

Schiff, Maurice and Walters, L. Alan. 2003. Regional integration and development. World Bank Working Paper. Washington DC: Oxford University Press.

Seaman, J., Leivesley, S. and Hogg, C. 1984. *Epidemiology of Natural Disasters.* Basel: Karger.

Sen, Amartya. 2000. *Development as Freedom.* New York: Random House.

Sharma, A. and Gupta, M. 1998. Reducing Urban Risk, India,TDR project progress report. Delhi, India: SEEDS

Smith, K. 2001. *Environmental Disasters.* 3rd edition. London: Routledge.

SNPMAD - PNUD. 2002. *Gestion del riesgo es igual a desarollo - lecciones de la experiencia.*

Stephen, Linda. 2002. From Wisner, B. 2002, background paper, invited contribution.

Stewart, Frances, Fitzgerald, Valpy and Associates. 2001. *War and Underdevelopment: Volume 1: The Economic and Social Consequences of Conflict.* Queen Elizabeth House Series in Development Studies.

Strand H., Wilhelmsen, L. and Gleditsch, N.P. 2003. *Armed Conflict Dataset Codebook.* Oslo: PRIO.

Tobin, G. and Montz, B. 1997. *Natural Hazards: Explanation and Integration.* New York: Guilford.

Twigg, J. 2001. *Corporate Social Responsibility and Disaster Reduction: A Global Overview.* London: Benfield Greig Hazard Research Centre, University College London.

_________. 2002. The Human Factor in Early Warnings: Risk Perception and Appropriate Communications. In Zschau, J. and Kueppers, A. (Eds.) *Early Warning Systems for Natural Disaster Reduction:* 19-26. Berlin: Springer-Verlag.

_________ and Bhatt, M. 1998. *Understanding Vulnerability: South Asian Perspectives.* London and Colombo: IT Publications.

UN (United Nations) 2000. United Nations Millennium Declaration,General Assembly Resolution A/RES/55/2, September 2000: 6.

_________. 2002. *Documents Related to Disaster Reduction. Volume 2, 2000-2002.* www.unisdr.org/unisdr/UNseries2.htm

_________. 2003.Millennium Declaration:Report of the Secretary-General, UN General Assembly, 2 September 2003. UNDP *Human Development Report 2003.* www.actionaid.org/ourpriorities/downloads/halfwaythere.pdf

_________. 2003. Millennium Development Goals, March 2003. New York: UN. www.un.org/millenniumgoals

UNCRD (United Nations Centre for Regional Development) 2003. *Sustainability in Grass Roots Initiatives: Focus on Community Based Disaster Management,* Kobe, Japan.

UNCTAD (United Nations Conference on Trade and Development). 2002. *The Least Developed Countries Report, 2002, Escaping the Poverty Trap.* New York and Geneva: UNCTAD.

UNDESA (Department of Economic and Social Affairs) Population Division. 2002. *World Urbanization Prospects.*

UNDESA and United Nations Centre for Human Settlements (HABITAT).2001. *Compendium of Human Settlements Statistics 2001, Sixth Issue.* New York: UN

UNDP (United Nations Development Programme) 1997. *Governance for Sustainable Human Development.*

_________. 2002a. Expert Group Meeting on the Role of Regional Organizations in Strengthening National Capacities for Disaster Reduction, Geneva.

_________. 2002b. *Conceptual Shifts in Sound Planning: Towards an Integrated Approach to HIV/AIDS and Poverty.*

_________. 2003a. *Disease, HIV/AIDS and Capacity Limitations: A Case of the Public Agriculture Sector in Zambia.*

_________. 2003b. Bureau for Crisis Prevention and Recovery (BCPR) Mission Report to Bolivia 2003.

_________. 2003c. National Human Development Report, UNDP Colombia, El Conflicto, callejón con salida.

_________. 2003d. *Human Development Report 2003.* New York: UNDP.

UNHABITAT (United Nations Centre for Human Settlements) *Cities in a Globalizing World 2001.*

U.S. Agency for International Development (USAID) 2002. Mozambique 1999-2000 Floods Impact Evaluation: Resettlement Grant Activity, July 2002. Emergency Recovery: Agriculture and Commercial Trade, Abt Asscs. Inc. (with Afrisurvey and Caresoft Lda.), Agricultural Policy Development Project (APD). Washington DC: USAID

Varley, A. (Ed.) 1994. *Disasters, Development and Environment.* Chichester: Wiley.

Vasta, Krishna. 2002. Microfinance for Disaster Risk Management, background note.

Vermieren, Jan. 2000. Risk Transfer and Finance Experience in the Caribbean. In *Managing Disaster Risk in Emerging Economies.* Washington, DC: World Bank.

WHO (World Health Organization) 1990. *Health For All When a Disaster Strikes.* Vol. 2. Geneva: WHO/EPR.

_________. 2002. Informe sobre la salud en el mundo. Reducir los riesgos y promover una vida sana.

Wilches-Chaux, Gustavo. 1993. La Vulnerabilidad Global. In Maskrey, Andrew (Ed.) *Los Desastres no San Naturales.* Bogota, Colombia: La Red.

_________. 1998. Auge, Caida y Levantada de Felipe Pinillo, Mecanico y Soldador o Yo Voy a Correr el Riesgo: Guia de La Red para la Gestion Local de Riesgos. Quito, Ecuador: La Red.

Winchester, P. 1992. *Power, Choice and Vulnerability: A Case Study in Disaster Mismanagement in South India.* London: James and James Science Publishers.

Wisner, B. 1993. Disaster Vulnerability: Scale, Power and Daily Life. *Geojournal* 30 (2): 127-40.

_________. 2000.The Political Economy of Hazards: More Limits to Growth? *Environmental Hazards* 20:59-61.

_________. 2001. Risk and the Neoliberal State: Why Post-Mitch Lessons Didn't Reduce El Salvador's Earthquake Losses. *Disasters* 25 (3): 251-268.

_________. 2003. Changes in Capitalism and Global Shifts in the Distribution of Hazard and Vulnerability. In Pelling, M. (Ed.) *Natural Disasters and Development in a Globalizing World.* London: Routledge.

_________ and Blaikie, P., Cannon, T. and Davis, I. 2003. *At Risk Natural Hazards, People's Vulnerability and Disasters, 2nd Edition.* London: Routledge.

Woolcock, M. 1998. Social capital and economic development: toward a theoretical synthesis and policy framework. *Theory and Society* 27 (2): 151-208.

World Bank. 1999. *Turkey: Marmara Earthquake Assessment.* Turkey Country Office. Washington, DC: World Bank.

_________. 2000. A Review of the Safer Housing Activities in Antigua/Barbuda, St Kitts/Nevis and St Lucia at www.oas.org/pgdm/document/houserev.doc

_________. 2001. *World Development Indicators 2001.* Washington DC: World Bank.

_________. 2002. *Poverty and Climate Change: Reducing the Vulnerability of the Poor.* A joint publication with the African Development Bank; Asian Development Bank; Department for International Development, U.K.; Directorate General for Development, European Commission; Federal Ministry for Economic Cooperation and Development, Germany; Ministry of Foreign Affairs, Development Cooperation, the Netherlands; OECD, UNDP and UNEP. Washington, DC: World Bank. www.worldbank.org/povcc

Zevallos, Othon. 1996. In Fernandez Maria Augusta, *Cities at Risk: Environmental Degradation, Urban Risk and Disaster.* Lima: La Red

Statistical References

Anand, S. and Sen, Amartya. 2000. 'The Income Component of the Human Development Index', *Journal of Human Development,* Vol. 1, No. 1.

Anderson, M. and Woodrow, P. 1989, *Rising from the Ashes: Development Strategies in Times of Disaster.* Westview Press, Boulder, CO, U.S.

Birdwell,K.R., Daniels, R.C. 1991. A Global Geographic Information System Data Base of Storm Occurrences and Other Climatic Phenomena Affecting Coastal Zones (1991). http://cdiac.esd.ornl.gov/ndps/ndp035.html

Blaikie, P. et al. 1996. *At Risk: Natural Hazards, Peoples Vulnerability and Disasters.* Routledge.

Blong, R.J. 1984. *Volcanic Hazards, A Sourcebook on the Effects of Eruptions.* Academic Press Australia.

Bolt, B.A., Horn, W.L.,Macdonald, G.A., and Scott, R.F. 1975. *Geological Hazard.* Berlin/Heidelberg/New York: Springer-Verlag.

Burton, I., Kates, R.W. and White, G.F. 1993: *The Environment as Hazard, Second Edition.* New York/London: Guilford Press, 290 pp. [Pp. 31-47]

Cardona, O.D. 2003. 'The notion of disaster risk: conceptual framework for integrated management'. In *Indicators for Disaster Risk Management,* Operation ATN/JF-7907-RG, Report Phase I, IADB-IDEA/Universidad Nacional de Colombia, Manizales, Colombia.

Carter, N. 1991. *Disaster Management, a disaster Manager's Handbook.* Manila: Asian Development Bank.

Coburn,A.W., Spence, R.J.S. and Pomonis,A.1991: *Vulnerability and Risk Assessment.* UNDP Disaster Management Training Program 57 pp.

Demuth, S. and Stahl, K. 2001. *Assessment of the Regional Impact of Droughts in Europe (ARIDE), Final Report,* Institute of Hydrology, University of Freiburg, Freiburg, Germany.

Giardini, D. 1999. *Annali di Geofisica, the global seismic hazard assessment program (GSHAP) 1992-1999,* Instituto Nazionale di Geofisica, Volume 42, N. 6, December 1999, Rome, Italy.

Gibson, J.L. 1998. *Social Networks and Civil Society in Processes of Democratisation.* Studies in Public Policy # 301, Centre for the Study of Public Policy, University of Strathclyde.

Herd, D.G. 1982. *Glacial and volcanic geology of the Ruiz-Tolima Volcanic Complex,* Cordillera Central, Colombia: Publicaciones Geológicas Especiales del INGEOMINAS, no. 8, 48 p.

Holland, G.J. 1980. An analytic model of the wind and pressure profiles in hurricanes. *Monthly Weather Review,* 108, 1212-1218.

Landsea, Christopher W. 2000. NOAA/AOML, FAQ: Hurricanes, Typhoons, and Tropical Cyclones. www.aoml.noaa.gov/hrd/tcfaq/tcfaqA.html#A1

Le Marechal, A. 1975. *Carte geologique de l'ouest du Cameroun et de l'Adamaoua,* 1:1,000,000; ORSTOM.

Newhall, C.G. and Self, S. 1982.The volcanic explosivity index (VEI): an estimate of explosive magnitude for historical volcanism. *Jour. Geophys. Res.* (Oceans & Atmospheres), 87:1231-8.

Peduzzi, P., Dao H., Herold, C., Mouton, Frédéric. 2003. *Global Risk And Vulnerability Index Trends per Year (GRAVITY), Phase IIIa: Drought analysis,* scientific report UNDP/BCPR, Geneva, Switzerland.

_________. 2002. *Global Risk and Vulnerability Index Trends per Year (GRAVITY), Phase II: Development, analysis and results,* scientific report UNDP/BCPR, Geneva, Switzerland.

_________ and Rochette, D. 2001. *Feasibility Study Report On Global Risk And Vulnerability Index Trends per Year (GRAVITY),* scientific report UNDP/BCPR, Geneva, Switzerland.

Schloemer, R.W. 1954. *Analysis and synthesis of hurricane wind patterns over Lake Okehoee,* Fl. Hydromet Rep. 31, 49 pp. [Govt. Printing Office, No. C30.70:31].

Simkin, T. and Siebert, L. 1994. *Volcanoes of the World.* Washington, DC: Geoscience Press.

Smith, K. 1996. *Environmental Hazards, Assessing Risk and Reducing Disaster.* London, New York: Routldlege.

Tobin,G.A. and Montz, B.E.1997. *Natural Hazards, Explanation and Integration.* New York, London: Guildford Press.

UNDP. 2002. A Climate Risk Management Approach to Disaster Reduction and Adaptation to Climate Change, UNDP Expert Group Meeting, Havana, Cuba, June 19-21, 2002.

UNDRO (United Nations Disaster Relief Coordinator) 1979. Natural Disasters and Vulnerability Analysis in *Report of Expert Group Meeting* (9-12 July 1979). Geneva: UNDRO. 49 pp.

UNEP. 2002. GEO: Global Environment Outlook 3. Past, present and future perspectives, UNEP.

Internet References

ActionAid. 2002. 'Halfway There' www.actionaid.org/ourpriorities/downloads/halfwaythere.pdf

Anderson, E., Brakenridge, G.R., 2001. NASA-supported Dartmouth Flood Observatory. www.dartmouth.edu/artsci/geog/floods/index.html.

Asian Disaster Preparedness Center. 2003. www.adpc.net/audmp/audmp.html , www.adpc.net/audmp/India.html

Babin, S. and Sterner, R., 2001. Atlantic Hurricane Track Maps & Images, http://fermi.jhuapl.edu/hurr/index.html

Birdwell K.R. and Daniels, R.C., 1991. A Global Geographic Information System Data Base of Storm Occurrences and Other Climatic Phenomena Affecting Coastal Zones,1991. http://cdiac.esd.ornl.gov/ndps/ndp035.html

Caribbean Disaster Emergency Response Agency, www.cdera.org/doccenter/publications/CDM%20Strategy%20FDF.pdf

CIESIN,IFPRI,WRI, 2000.Gridded Population of the World (GPW), Version 2, http://sedac.ciesin.org/plue/gpw/

Coordination Center for the Prevention of Natural Disasters in Central America. 2003. www.cepredenac.org/11_engl/11_index.htm

Council of the National Seismic System, 2002. Earthquake Catalog, http://quake.geo.berkeley.edu/cnss/

Deichmann, Uwe, 1996. GNV197 - Human Population and Administrative Boundaries Database for Asia, UNEP/GRID-Geneva, www.grid.unep.ch/data/grid/gnv197.php

DHI Water and Environment. 2002. 'Environmental Improvement and Flood Mitigation Project for the Klang River, Malaysia (2001-2002)' www.dhi.dk/dhiproj/Country/Malaysia/Klang/

Disaster Mitigation for Sustainable Livlihoods Program. 2003. www.egs.uct.ac.za/dimp/

Donlin C. and Fitzgibbon, T., 2001. Geopubs – Online Geologic Publications of the Western United States, USGS: http://geopubs.wr.usgs.gov/docs/wrgis/fact

Economic Commission for Latin America and the Caribbean, www.eclac.cl/analisis/TIN53.htm#6

FAO (Food and Agriculture Organisation) 1998. 'The State of Food and Agriculture 1998' www.fao.org/docrep/W9500E/w9500e07.htm

Giardini, D., Grünthal, G., Shedlock K., Zhang, P., 2000. Global Seismic Hazard Assessment Program, www.seismo.ethz.ch/GSHAP/

Global Identifier Number (GLIDE) 2001. www.glidenumber.net/

Global Volcanism Program, National Museum of Natural History, E-421, Smithsonian Institution, Washington DC 20560-0119, www.nmnh.si.edu/gvp/index.htm

_________. Volcanic Activity Reports, Pinatubo, Index and All Reports, National Museum of Natural History, Smithsonian Institution, Washington, DC: www.nmnh.si.edu/gvp/volcano/region07/luzon/pinatubo/var.htm#1605

Grameen Bank. 2003. www.grameen-info.org

International Decade for Natural Disaster Reduction, www.unisdr.org/unisdr/indexidndr.html, www.unisdr.org/dialogue/basicdocument.htm#framework

International Institute for Environment and Development, www.iied.org/human/eandu/eandu_details.html

IRI/Columbia University, National Centers for Environmental Prediction, Climate Prediction Center. 2002. Merged Analysis of Precipitation (CMAP) monthly gridded precipitation, http://iridl.ldeo.columbia.edu

ISRIC, UNEP. 1990. Global Assessment of Human Induced Soil Degradation (GLASOD), www.grid.unep.ch/data/grid/gnv18.php

Landsea Christopher W. 2000. NOAA/AOML, FAQ: Hurricanes, Typhoons, and Tropical Cyclones. www.aoml.noaa.gov/hrd/tcfaq/tcfaqA.html#A1

Leeman, W.P. 1999. Volcanism & Volcanic Hazards Summary of basic terms and concepts, Rice University, www.ruf.rice.edu/~leeman/volcanic_hazards.html

Livelihoods Connect (DFID) 2003. 'Livelihoods Security in an Emergency Project' www.livelihoods.org/post/Docs/emergency.doc

Morrissey, Oliver. 2001. Research Paper: Pro Poor Conditionality for Aid and Debt Relief in East Africa. Nottingham University, www.nottingham.ac.uk/economics/credit/research/papers/CP.01.15.PDF

OFDA/CRED. 2001. EM-DAT: The OFDA/CRED International Disaster Database, www.cred.be/emdat

OAS (Organisation of American States) 2001. 'The Caribbean Disaster Mitigation Project in the Dominican Republic' www.oas.org/cdmp/document/papers/tiems.htm , www.oas.org/cdmp/document/papers/tiems.htm

Overseas Development Institute for DFID, 'Keysheets' www.keysheets.org/ppip/purple_2_disasters.pdf

Peduzzi, P. 2000. Insight of Common Key Indicators for Global Vulnerability Mapping. Presentation for the expert meeting on Vulnerability and Risk Analysis and Indexing, Geneva 11-12 September 2000, UNEP/DEWA/GRID-Geneva, www.grid.unep.ch/activities/earlywarning/preview/appl/reports/reports.htm

_________. 2001. Project of Risk Evaluation, Vulnerability Indexing and Early Warning (PREVIEW), UNEP/DEWA/GRID-Geneva, www.grid.unep.ch/activities/earlywarning/preview/index.htm

PRSP Monitoring and Synthesis Project, www.prspsynthesis.org/connections9.pdf

Third World Network. 'Caribbean: Plan needed to mitigate impact of natural disasters' www.twnside.org.sg/title/mitigate.htm

Topinka, L. 2001. Cascades Volcano Observatory, USGS, Vancouver, Washington, U.S., http://vulcan.wr.usgs.gov/Volcanoes/

Transparency international, 2001. Global Corruption Report 2001, www.transparency.org

U.S. Geological Survey. 1997.HYDRO1k, an Elevation Derivative Database, http://edcdaac.usgs.gov/gtopo30/hydro

UNDP. 2003a. Human Development Indicators, www.undp.org/hdr2003

_________. 2003b. Millennium Development Goals, www.undp.org/mdg/countryreports.html

_________. 2003c. Bureau for Crisis Prevention and Recovery, Disaster Reduction and Recovery Unit, www.undp.org/erd/disred/index.htm

UNEP, CGIAR, NCGIA. 1996. Human Population and Administrative Boundaries Database for Asia, www.grid.unep.ch/data/grid/human.php

UNEP/GRID, 2002. GEO-3 Data portal, http://geodata.grid.unep.ch/

UNEP. 2002. Division of Technology, Industry and Economics, Awareness and Preparedness for Emergencies on a Local Level (APELL),APELL in Korea, www.uneptie.org/pc/apell/programme/casestudies/casestud.html

UNHABITAT (United Nations Centre for Human Settlements) www.unhabitat.org/habrdd/global.html, www.unchs.org/istanbul+5/14.pdf

VHP (Volcano Hazards Program) 2000. Strategy for reducing volcanic risk, U.S. Department of the Interior, U.S. Geological Survey, Menlo Park, CA. U.S.: http://volcanoes.usgs.gov/About/What/Assess/

World Bank. 2003a. Urban Development, www.worldbank.org/html/fpd/

_________. 2003b. Poverty Net, http://worldbank.int/poverty/wbactivities/erl/index.htm

World Water Day 2003, www.worldwaterday.org/2001/thematic/floods.html

Appendix
INTERNATIONAL INITIATIVES AT MODELLING RISK

This Appendix presents a review of international indicator projects dealing with risk and development. These projects are presented under four headings: Disaster Risk Reduction, Disaster Risk Reduction and Environmental Management,Environmental Management and Sustainable Development, and Sustainable Human Development. Every effort was made to ensure this list was a complete at the time of publication — apologies to any groups or individuals working on projects that have not been included.

A.1 Disaster Risk Reduction

Identification of Global Natural Disaster Hotspots

The Hotspots project aims to generate a global natural disaster risk assessment. Risks of human and economic losses will be estimated through spatial analysis by assessing the exposure of a global set of element at risk — people, infrastructure and economic activities – to all major natural hazards — droughts,floods,storms,earthquakes,volcanoes and landslides. The analysis will be based on the actual geographic distributions of these phenomena rather than on national level statistics. Risks of losses among the elements at risk posed by each hazard individually, will be aggregated across varying time scales to arrive at the aggregate, multi-hazard risk. A series of case studies will be undertaken as the second component of the Hotspots project to complement the global-scale analysis.

For more information please see the websites
www.proventionconsortium.org files/hotspots2002/dilley.pdf and
http://doherty.ldgo.columbia.edu/CHHR/Hotspot/hotspotmain.html

HAZUS

Undertaken by the United States Federal Emergency Management Agency (FEMA), Hazards U.S. (HAZUS) uses Geographic Information Systems (GIS) technology to compute estimates of damage and losses that could result from earthquake events. To support FEMA's mitigation and emergency preparedness efforts, HAZUS is being expanded into HAZUS-MH, a multi-hazard methodology with new modules for estimating potential losses from wind and flood (coastal and riverine) hazards.

For additional information regarding HAZUS please visit the following websites:
www.nibs.org/hazusweb/ and
www.fema.gov/hazus/index.shtm

Tyndall Climate Change/Disaster Risk Index

The UK based Tyndall Centre for Climate Change Research uses data relating to natural disasters for the assessment of recent historical and current risk associated with climatic variability. Current risk associated with extreme climate events is used as a proxy for risk associated with climate change in the future. The data used is derived from EM-DAT with population data from the World Bank. The results of the risk study will be examined within the context of considerations of vulnerability. Once high-risk countries have been identified it will be necessary to examine the vulnerability of different population groups at a sub-national scale in order to target resources for capacity building; adaptation funds will be useless if they are not employed in a process driven fashion that takes into account the particular geographical, political, economic and social circumstance of the vulnerable groups in question.

For more information please see:
www.tyndall.ac.uk/publications/working_papers/working_papers.shtml

A.2 Disaster Risk Reduction and Environmental Management

Environmental Vulnerabilities Index

The South Pacific Applied Geoscience Commission (SOPAC) Environmental Vulnerability Index (EVI) is among the first tools being developed to focus environmental management at the same scale that environmentally significant decisions are made, and to focus these on outcomes. The method uses 54 indicators to assess the vulnerability of the environment at the national scale. The EVI has been designed to reflect the status of a country's environmental vulnerability, the extent that the natural environment is prone to damage and degradation. It does not address the vulnerability of the social, cultural, or economic environment, nor the environment that has become dominated by these same human systems.

For more information regarding the EVI please visit the following website: www.sopac.org

Small Islands Developing States Index

Paragraphs 113 and 114 of the Programme of Action for the Sustainable Development of Small Island Developing States that was endorsed by the General Assembly in 1994 by resolution 49/122 call for the development of a vulnerability index for Small Island Developing States (SIDS). Accordingly, the UN Department of Economic and Social Affairs (UNDESA) undertook initial studies in 1996 in order to provide a conceptual framework for the development of a vulnerability index. This index is still in the development stage. In the Caribbean, ECHO has developed a Composite Vulnerability Index to compare losses to natural disaster events in the region. During 2002-2003, the Economic Commission for Latin America and the Caribbean/Caribbean Development and Cooperation Committee (ECLAC/CDCC) has explored potential methodologies for a social vulnerability index for Caribbean SIDS.

For further information regarding the Small Island Developing States Index, please visit the website: www.un.org/esa/sustdev/aboutsids.htm

For the ECHO Composite Vulnerability Index please see: www.disaster.info.desastres.net/dipecho/

The Water Poverty Index

The Water Poverty Index assesses communities and countries by water scarcity, examining both physical and socio-economic factors. The Index is based on the formulation of a framework that incorporates six variables: resources, access, capacity, use, environmental and geospatial. Of 147 countries with relatively complete data, most in the top half are either developed or richer developing countries.

For further information please visit the website: www.nerc-wallingford.ac.uk/research/WPI/

A.3 Environmental Management and Sustainable Development

Bellagio Principles: Guidelines for the Practical Assessment of Progress Toward Sustainable Development

These principles deal with four aspects of assessing progress toward sustainability. Principle 1 establishes a vision of sustainable development. Principles 2 through 5 deal with the content of any assessment and the need to merge a sense of the overall system with a practical focus on current priority issues. Principles 6 through 8 deal with key issues of the process of assessment, while Principles 9 and 10 deal with the necessity for establishing a continuing capacity for assessment.

For additional information please visit the following website: http://iisd.ca/measure/bellagio1.htm

Dashboard of Sustainability Indicators

The Dashboard of Sustainability was presented at the World Summit on Sustainable Development (WSSD) in Johannesburg. It is based on the UN Commission on Sustainable Development (CSD) indicator set and contains 19 social,20 environmental,14 economic and 8 institutional indicators. It includes data for over 200 countries. The latest version,RioJo, allows a comparison of the global situation at the time of the Rio Summit in 1992 with the current state of the world.

For more information please visit the IISD homepage: www.iisd.org

Ecological Footprint Accounts

Ecological Footprint Accounts document humanity's demands on nature. A population's Ecological Footprint is the biologically productive area needed to produce the resources used and absorb the waste generated by that population. Ecological Footprint Accounts calculate the combined size of these areas. The average world citizen has an Ecological Footprint of 2.3 global hectares (5.6 acres),the average German's is 4.7 global hectares (12 acres), and the average American's is 9.6 global hectares (24 acres).

For more information please see the website: www.redefiningprogress.org/programs/sustainability/ef/

Environmental Sustainability Index

The Environmental Sustainability Index (ESI) works towards the development of a measure of overall progress of global environmental sustainability. Currently incorporating 142 countries, the 2002 ESI scores are based upon a set of 20 core indicators. The ESI tracks the relative success of each country in the five core components of environmental systems: reducing stress, reducing human vulnerability, social and institutional capacity, and global stewardship.

For more information please see the following websites: www.weforum.org, www.ciesin.columbia.edu, www.yale.edu/envirocenter

Millennium Ecosystem Assessment

The Millennium Ecosystem Assessment undertakes an analysis of the capacity of an ecosystem to provide goods and services important for human development. The fundamental unit of interest is the ecosystem itself. The approach taken is to assess the capacity of the system to provide various goods and services and then to evaluate the trade-offs among those goods and services.

For more information regarding the Millennium Ecosystem Assessment please visit the following website: www.millenniumassessment.org/en/about/index.htm

Pilot Environmental Performance Index

The Environmental Performance Index (EPI),launched in 2002, permits national comparisons on efforts to manage a narrow set of common policy objectives concerning air and water quality, climate change and ecosystem well-being. The EPI enables benchmarking of progress towards meeting immediate national policy objectives, facilitates judgements about environmental performance, and can be used to identify important differences in performance that may warrant intervention and investigation.

For more information please see the following websites: www.weforum.org, www.ciesin.columbia.edu, www.yale.edu/envirocenter

A.4 Sustainable Human Development

The Human Development Index

UNDP's Human Development Index (HDI) measures a country's achievements in three aspects of human development:longevity, knowledge and a decent standard of living. Although the HDI is a useful tool it is not enough to measure a country's level of development. A fuller picture of a country's level of human development requires analysis of other human development indicators and information.

For further information please visit the following UNDP website: http://hdr.undp.org

The Human Poverty Index

UNDP's Human Poverty Index for developing countries (HPI-1) measures deprivations in the same three aspects of human development as the HDI (longevity, knowledge and a decent standard of living). The Human Poverty Index for industrialised countries (HPI-2) includes social exclusion. Many National Human Development Reports now break down the HPI by district level or language group to identify the areas or social groups within the country most deprived in terms of human poverty. The results can be dramatic, creating national debate and helping to reshape policies.

For more information please visit the following webpage: http://hdr.undp.org/statistics/faq.cfm

The Human Insecurity Index

The Index of Human Insecurity is a classification system that distinguishes countries based on how vulnerable or insecure they are. The index uses indicators of sustainable development, although parallels with indicators of human well-being and social indicators are evident.

For more information please visit the following website: www.gechs.org/aviso/avisoenglish/six_lg.shtml

Freedom House Index

Freedom in the World is an institutional effort by Freedom House to monitor the progress and decline of political rights and civil liberties in 192 nations and in major related or disputed territories. The Survey rates each country on a seven-point scale for political rights and civil liberties and divides the world into three broad categories: "Free", "Partly Free", and "Not Free".

For more information please visit the Freedom House homepage: www.freedomhouse.org

Transition Index

This index offers analysis of the transition to market economies and macroeconomic performance in Central and Eastern Europe and the Commonwealth of Independent States (CIS), drawing on the European Bank for Reconstruction and Development's (EBRD) experience as an investor in the region. Country-by-country assessments include macroeconomic tables, output and expenditure, and foreign direct investment. They also provide key data on liberalisation,stabilisation, privatisation, enterprise reform, infrastructure, financial institutions and social reform.

For more information please visit the EBRD homepage: www.ebrd.com

Human Rights Indicators

This project measures the commitment of governments to respect and fulfil human rights. Four factors are part of their assessment of commitment: an index measuring commitment to international and regional human rights standards by governments, an index of civil and political human rights violations by governments, an index approximating commitment to fulfilment of economic, social and cultural rights, and an index measuring in a preliminary way, commitment to gender equality by governments.

For more information regarding the Human Rights Indicators please visit the Danish Centre for Human Rights webpage: www.humanrights.dk/departments/PP/PA/Concept/Indicato/

AIDS Program Effort Index

The AIDS Program Effort Index (API) measures the amount of effort put into national AIDS programs by both domestic and international organisations. The API was implemented in 40 countries in 2000.

For more information regarding the API please visit the following website: www.tfgi.com/Api_final.doc

GLOSSARY OF TERMS

The explanations offered here are not formal UNDP definitions. To aid comparability, these definitions are similar to those used in the ISDR Secretariat publication, *Living with Risk: A Global review of Disaster Reduction Initiatives.*

Armed conflict: A contested incompatibility that concerns government and/or territory where the use of armed force between two parties, of which at least one is the government of a state, results in at least 25 battle-related deaths.[1]

Civil society: A realm of political action lying between the household and the state but excluding for profit private sector organisations. Civil society organisations are commonly exemplified by non-governmental and community-based developmental organisations, but also include a wide range of other groups including sports clubs, interest groups, trade unions etc.

Coping capacity: The manner in which people and organisations use existing resources to achieve various beneficial ends during unusual, abnormal and adverse conditions of a disaster phenomenon or process.

Disaster risk management: The systematic management of administrative decisions,organisation, operational skills and abilities to implement policies, strategies and coping capacities of the society or individuals to lessen the impacts of natural and related environmental and technological hazards.

Disaster risk reduction: The systematic development and application of policies, strategies and practices to minimise vulnerabilities, hazards and the unfolding of disaster impacts throughout a society, in the broad context of sustainable development.

Empowerment: A process in which individuals learn by their own actions to become fully engaged in shaping their development potential. The process is necessarily self-led, but benefits from facilitation by supporting actors.

Human vulnerability: A human condition or process resulting from physical, social, economic and environmental factors, which determine the likelihood and scale of damage from the impact of a given hazard.

Governance: Governance is the exercise of economic, political and administrative authority to manage a country's affairs at all levels. It comprises the mechanisms, processes and institutions, through which citizens and groups articulate their interests, exercise their legal rights, meet their obligations and mediate their differences.

Income poverty: A status whereby a lack of financial resources limits the ability of an individual or household to meet basic needs. What is included in basic needs is culturally determined so that different levels of financial status may be described as conveying relative forms of income poverty.

Livelihood: The means by which an individual or household obtains assets for survival and self-development. Livelihood assets are the tools (skills, objects, rights, knowledge, social capital) applied to enacting the livelihood.

Natural disaster: A serious disruption triggered by a natural hazard causing human, material, economic or environmental losses, which exceed the ability of those affected to cope.

Natural disaster, slow onset: A disaster event that unfolds alongside and within development processes. The hazard can be felt as an ongoing stress for many days, months or even years. Drought is a prime example.

Natural disaster, rapid onset: A disaster that is triggered by an instantaneous shock. The impact of this disaster may unfold over the medium- or long-term. An earthquake is a prime example.

Natural hazards: Natural processes or phenomena occurring in the biosphere that may constitute a damaging event.

Physical exposure: Elements at risk, an inventory of those people or artefacts that are exposed to a hazard.

Risk: The probability of harmful consequences, or expected loss of lives, people injured, property, livelihoods, economic activity disrupted (or environment damaged) resulting from interactions between natural or human induced hazards and vulnerable conditions. Risk is conventionally expressed by the equation:
Risk = Hazard x Vulnerability

Resilience: The capacity of a system, community or society to resist or to change in order that it may obtain an acceptable level in functioning and structure. This is determined by the degree to which the social system is capable of organising itself, and the ability to increase its capacity for learning and adaptation, including the capacity to recover from a disaster.

Social capital: A shorthand term used to describe a combination of social norms (such as trust), relationships (such as reciprocity) and ties (such as hierarchical clientalism or horizontal group bonds) held by an individual or predominant within a social arena.

Sustainable development: Development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts: the concept of 'needs', in particular the essential needs of the world's poor, to which overriding priority should be given; and the idea of limitations imposed by the state of technology and social organisation on the environment's ability to meet present and future needs.

1. Strand H., Wilhelmsen, L. and Gleditsch, N.P. 2003. Armed Conflict Dataset Codebook, PRIO: Oslo

Statistical Annex

DISASTER RISK INDEX TABLES

TABLE 1 DISASTER RISK INDEX SUMMARY TABLE, 1980 - 2000

	Number of people killed per year	Average number of people killed per million inhabitants	Average HDI 1980-2000	Gross Domestic Product Purchasing Power Parity, 1990	Percentage of population infected by HIV/AIDS virus, 2001	Control of corruption 2002	Average percentage of people affected by conflicts per year, 1980 - 2000
Country Name (alphabetical order)	Killed per Year	Killed per million	HDI_{av}*	GDPcap (ppp)	%	Corruption	%population
Afghanistan	820.00	49.06	--	--	--	-1.35	98
Albania	0.76	0.25	0.725	2 843	--	-0.85	0
Algeria	150.71	6.02	0.693	4 502	0.04	-0.70	37
Angola	1.38	0.13	0.422	1 581	2.59	-1.12	79
Antigua and Barbuda	0.33	5.26	--	7 270	--	-0.84	0
Argentina	12.57	0.38	0.842	7 721	0.37	-0.77	0
Armenia	1 190.67	323.68	0.745	3 565	0.06	-0.72	0
Australia	9.95	0.59	0.936	17 271	0.06	1.91	0
Austria	1.48	0.19	0.921	18 664	0.12	1.85	0
Azerbaijan	2.29	0.29	0.738	4591	0.02	-1.07	0.8
Bahamas	0.24	0.89	0.82	14 521	2.29	1.41	0
Bahrain	--	--	0.824	12 088	--	0.95	0
Bangladesh	7 930.95	68.84	0.47	1 004	0.01	-1.12	4
Barbados	0.00	0.00	0.864	11 252	--	1.29	0
Belarus	0.33	0.03	0.782	7 031	0.15	-0.78	0
Belgium	0.43	0.04	0.935	19 411	0.08	1.57	0
Belize	0.67	3.21	0.776	3 633	1.23	-0.25	0
Benin	4.67	0.94	0.42	706	1.94	-0.61	0
Bhutan	10.57	5.44	0.477	882	--	0.91	0
Bolivia	20.43	3.12	0.648	1 826	0.05	-0.82	0
Bosnia and Herzegovina	0.00	0.00	--	--	--	-0.60	27
Botswana	1.48	1.26	0.577	4 911	20.91	0.76	0
Brazil	106.00	0.72	0.75	5 562	0.35	-0.05	0
Brunei Darussalam	--	--	0.857	14 727	--	0.32	0
Bulgaria	0.19	0.02	0.772	5 797	--	-0.17	0
Burkina Faso	2.10	0.24	0.32	636	4.26	-0.04	0
Burundi	0.86	0.14	0.309	722	6.00	-1.02	16
Cambodia	48.52	4.24	0.541	980	1.30	-0.90	75
Cameroon	1.76	0.13	0.506	1 561	6.05	-1.10	0
Canada	5.10	0.18	0.936	20 122	0.18	2.03	0
Cape Verde	1.52	4.92	0.708	2 926	--	0.33	0
Central African Republic	0.33	0.11	0.372	1 060	6.61	-1.02	3.6

TABLE 1 DISASTER RISK INDEX SUMMARY TABLE, 1980 - 2000

	Number of people killed per year	Average number of people killed per million inhabitants	Average HDI 1980-2000	Gross Domestic Product Purchasing Power Parity, 1990	Percentage of population infected by HIV/AIDS virus, 2001	Control of corruption 2002	Average percentage of people affected by conflicts per year, 1980 - 2000
Country Name (alphabetical order)	Killed per Year	Killed per million	HDI_{w}*	GDPcap (ppp)	%	Corruption	%population
Chad	147.38	25.89	0.359	766	1.82	-1.02	43
Chile	32.95	2.47	0.825	4 981	0.11	1.55	0
China	2 173.10	1.88	0.718	1 394	0.09	-0.41	0
Colombia	134.43	3.76	0.765	7 195	0.33	-0.47	100
Comoros	2.81	6.15	0.51	1 716	--	-0.73	0
Congo	0.10	0.04	0.502	760	3.60	-0.94	6
Costa Rica	8.48	2.61	0.821	5 288	0.27	0.88	0
Cote d'Ivoire	1.33	0.11	0.426	1 552	4.74	-0.86	0
Croatia	0.00	0.00	0.803	7 133	0.00	0.23	4
Cuba	7.24	0.68	--	--	0.03	-0.13	0
Cyprus	0.10	0.13	0.877	12 784	--	0.89	0
Czech Republic	1.38	0.13	0.844	--	0.00	0.38	0
Democratic People's Republic of Korea	12 887.76	605.90	--	--	--	-1.18	0
Democratic Republic of the Congo	3.05	0.07	0.429	1 290	2.53	-1.42	18
Denmark	0.86	0.17	0.921	19 513	0.09	2.26	0
Djibouti	8.57	17.66	0.447	--	--	-0.73	23.4
Dominica	0.14	1.99	--	--	--	0.52	0
Dominican Republic	22.19	3.11	0.722	3 361	1.47	-0.39	0
Ecuador	58.95	5.59	0.726	2 781	0.16	-1.02	0
Egypt	58.43	0.98	0.635	2 509	0.01	-0.29	0
El Salvador	103.52	19.01	0.701	2 969	0.38	-0.54	44
Equatorial Guinea	--	--	--	1 052	1.26	-1.89	0
Eritrea	0.00	0.00	0.416	--	1.44	0.04	70
Estonia	--	--	--	7 957	0.56	0.66	0
Ethiopia	14 330.33	272.57	0.321	486	3.26	-0.35	24
Fiji	7.29	10.08	0.757	3 804	0.04	0.12	0
Finland	0.00	0.00	0.925	17 797	0.02	2.39	0
France	15.86	0.28	0.924	17 966	0.17	1.45	0
Gabon	0.00	0.00	0.617	5 241	--	-0.55	0
Gambia	2.52	2.98	0.398	1 488	0.61	-0.83	0
Georgia	18.10	3.38	0.742	9 101	0.02	-1.03	0
Germany	2.52	0.03	0.921	18 224	0.05	1.82	0
Ghana	9.95	0.65	0.542	1 368	1.65	-0.40	0
Greece	14.76	1.44	0.881	11 464	0.08	0.58	0
Grenada	0.00	0.00	--	4 567	--	0.71	0
Guatemala	58.24	6.34	0.626	2 824	0.58	-0.71	76
Guinea	13.86	2.27	0.397	1 520	--	-0.58	3
Guinea-Bissau	0.05	0.06	0.339	686	1.39	-0.61	0
Guyana	0.00	0.00	0.704	2 858	2.29	-0.50	0
Haiti	93.14	13.72	0.467	1 638	3.51	-1.70	0
Honduras	732.90	143.61	0.634	2 074	0.87	-0.78	0
Hungary	2.52	0.25	0.829	9 447	0.03	0.60	0
Iceland	0.00	0.00	0.932	21 343	0.08	2.19	0
India	2 931.81	3.51	0.571	1 400	0.39	-0.25	3
Indonesia	373.90	2.06	0.677	1 952	0.05	-1.16	1
Iran (Islamic Republic of)	2 393.14	40.29	0.714	3 878	0.03	-0.38	22
Iraq	0.95	0.05	--	--	0.00	-1.43	71
Ireland	1.81	0.51	0.916	12 687	0.06	1.67	0
Israel	0.90	0.17	0.893	13 450	--	1.08	99
Italy	242.86	4.27	0.909	17 438	0.19	0.80	0
Jamaica	6.57	2.81	0.738	3 261	0.67	-0.46	0
Japan	351.29	2.87	0.928	20 183	0.01	1.20	0

TABLE 1 DISASTER RISK INDEX SUMMARY TABLE, 1980 - 2000

	Number of people killed per year	Average number of people killed per million inhabitants	Average HDI 1980-2000	Gross Domestic Product Purchasing Power Parity, 1990	Percentage of population infected by HIV/AIDS virus, 2001	Control of corruption 2002	Average percentage of people affected by conflicts per year, 1980 - 2000
Country Name (alphabetical order)	Killed per Year	Killed per million	HDI_{ur}*	GDPcap (ppp)	%	Corruption	%population
Jordan	1.33	0.35	0.714	3 304	--	0.00	0
Kazakhstan	5.86	0.35	0.742	6 095	0.04	-1.05	0
Kenya	19.29	0.78	0.514	977	7.99	-1.05	0
Kiribati	0.00	0.00	--	--	--	-0.44	0
Kuwait	0.10	0.06	0.818	--	--	1.06	0
Kyrgyzstan	2.86	0.62	0.707	3 608	0.01	-0.84	0
Lao People's Democratic Republic	5.95	1.36	0.476	900	0.03	-1.25	6
Latvia	--	--	--	8 487	--	0.09	0
Lebanon	1.19	0.44	0.758	1 870	--	-0.34	25
Lesotho	1.90	1.13	0.541	1 087	17.25	-0.28	0
Liberia	0.48	0.22	--	--	--	-0.98	28
Libyan Arab Jamahiriya	0.00	0.00	0.77	--	0.13	-0.82	0
Liechtenstein	--	--	--	--	--	1.29	0
Lithuania	0.29	0.08	0.803	8 534	0.04	0.25	0
Luxembourg	0.00	0.00	0.924	21 363	--	2.00	0
Madagascar	58.33	4.65	0.462	818	0.13	0.14	0
Malawi	23.76	2.43	0.397	445	7.86	-0.91	0
Malaysia	17.29	0.89	0.774	4 739	0.19	0.38	0
Maldives	0.00	0.00	0.739	3 611	--	0.04	0
Mali	1.81	0.20	0.378	582	0.95	-0.32	0
Malta	--	--	0.866	8 742	--	0.80	0
Marshall Islands	0.00	0.00	--	--	--	-0.02	0
Mauritania	107.05	52.63	0.437	1 167	--	0.23	0
Mauritius	0.33	0.31	0.765	5 597	0.06	0.53	0
Mexico	629.19	7.26	0.79	6 383	0.13	-0.19	0
Micronesia (Federated States of)	0.24	2.33	--	--	--	-0.44	0
Moldova, Republic of	3.05	0.71	0.699	5 216	0.13	-0.89	0
Mongolia	4.81	2.00	0.569	1 804	--	-0.14	0
Morocco	40.29	1.48	0.596	2 888	0.04	-0.04	0
Mozambique	4 827.71	327.51	0.323	521	6.33	-1.01	46
Myanmar	10.90	0.25	0.551	--	0.62	-1.37	74
Namibia	0.00	0.00	0.601	4 411	10.63	0.21	40
Nepal	242.52	13.58	0.48	883	0.24	-0.30	0
Netherlands	0.10	0.01	0.991	17 407	0.10	2.15	0
New Zealand	0.81	0.24	0.913	14 190	0.03	2.28	0
Nicaragua	173.95	39.84	0.635	1 721	0.11	-0.44	33
Niger	4.57	0.56	0.274	738	--	-1.10	0
Nigeria	17.43	0.17	0.455	764	2.99	-1.35	0
Norway	0.05	0.01	0.939	19 527	0.04	2.00	0
Oman	1.24	1.04	0.747	--	0.05	1.03	0
Pakistan	292.05	2.61	0.498	1 394	0.06	-0.73	0
Panama	4.24	1.70	0.784	3 871	0.88	-0.24	0
Papua New Guinea	12.76	3.30	0.534	1 580	0.34	-0.90	0
Paraguay	5.19	1.17	0.738	3 922	--	-1.22	0
Peru	110.62	5.22	0.743	3 251	0.20	-0.20	70
Philippines	1 059.86	17.49	0.749	3 332	0.01	-0.52	100
Poland	2.95	0.08	0.828	5 684	--	0.39	0
Portugal	7.29	0.73	0.874	11 176	0.31	1.33	0
Qatar	--	--	0.801	--	--	0.92	0
Republic of Korea	123.48	2.86	0.875	8 880	0.01	0.33	0
Romania	11.14	0.49	0.772	6 219	0.03	-0.34	0
Russian Federation	132.14	0.90	0.775	10 079	0.46	-0.90	0
Rwanda	2.29	0.34	0.395	952	6.29	-0.58	23

TABLE 1 DISASTER RISK INDEX SUMMARY TABLE, 1980 - 2000

	Number of people killed per year	Average number of people killed per million inhabitants	Average HDI 1980-2000	Gross Domestic Product Purchasing Power Parity, 1990	Percentage of population infected by HIV/AIDS virus, 2001	Control of corruption 2002	Average percentage of people affected by conflicts per year, 1980 - 2000
Country Name (alphabetical order)	Killed per Year	Killed per million	HDI_{w}*	GDPcap (ppp)	%	Corruption	%population
Saint Kitts and Nevis	0.29	6.91	--	6 334	--	0.40	0
Saint Lucia	2.76	21.74	--	4 360	--	0.40	0
Saint Vincent and the Grenadines	0.14	1.37	--	3 631	--	0.40	0
Samoa	1.00	6.28	0.701	4 325	--	-0.06	0
Sao Tome and Principe	0.00	0.00	--	--	--	-0.25	0
Saudi Arabia	1.52	0.13	0.754	9 401	--	0.57	0
Senegal	8.90	1.22	0.423	1 199	0.27	-0.17	6
Seychelles	0.24	3.08	--	--	--	0.52	0
Sierra Leone	4.05	1.02	0.258	894	3.71	-0.82	24
Singapore	--	--	0.876	12 783	0.08	2.30	0
Slovakia	2.67	0.49	0.831	9 028	--	0.28	0
Slovenia	0.00	0.00	0.874	--	0.01	0.89	3.7
Solomon Islands	5.00	15.42	--	1 801	--	-0.86	0
Somalia	148.62	19.88	--	--	0.47	-1.19	3
South Africa	62.38	1.67	0.702	8 282	11.42	0.36	22
Spain	13.24	0.34	0.908	12 848	0.31	1.46	0
Sri Lanka	27.86	1.66	0.735	2 036	0.03	-0.14	65
Sudan	7 160.00	275.43	0.439	803	1.35	-1.09	65
Suriname	--	--	0.758	2 508	0.89	0.19	0
Swaziland	26.33	34.77	0.583	3 630	17.60	-0.26	0
Sweden	0.00	0.00	0.936	18 284	0.04	2.25	0
Switzerland	0.76	0.11	0.924	24 154	0.27	2.17	0
Syrian Arab Republic	0.00	0.00	0.7	2 215	--	-0.29	4
Taiwan	134.33	6.36	--	--	--	0.81	0
Tajikistan	82.95	14.64	0.66	2 796	0.00	-1.07	15
Thailand	108.76	1.91	0.757	3 835	1.05	-0.15	11
The former Yugoslav Republic of Macedonia	0.00	0.00	0.766	5 011	--	-0.73	0
Togo	0.14	0.04	0.489	1 400	3.22	-0.68	0
Tonga	0.38	3.97	--	--	--	-0.44	0
Trinidad and Tobago	0.24	0.19	0.798	6 035	1.73	-0.04	0
Tunisia	8.43	1.11	0.714	3 900	--	0.35	0
Turkey	972.24	16.46	0.735	4 834	--	-0.38	3
Turkmenistan	0.00	0.00	0.73	5 962	--	-1.21	0
Tuvalu	0.00	0.00	--	--	--	--	0
Uganda	12.86	0.66	0.435	746	2.50	-0.92	45
Ukraine	3.48	0.07	0.742	6 894	0.51	-0.96	0
United Arab Emirates	--	--	0.809	20 204	--	1.19	0
United Kingdom of Great Britain & Northern Ireland	9.76	0.17	0.923	16 706	0.06	1.97	2
United Republic of Tanzania	22.24	0.75	0.436	453	4.03	-1.00	0
United States of America	253.57	0.97	0.934	23 447	0.32	1.77	0
Uruguay	0.10	0.03	0.828	6 177	0.19	0.79	0
Uzbekistan	4.95	0.22	0.698	--	0.00	-1.03	0
Vanuatu	5.10	33.30	--	2 445	--	-0.44	0
Venezuela	1 449.38	70.54	0.765	5 050	--	-0.94	0
Viet Nam	573.14	8.36	0.682	--	0.17	-0.68	10
Yemen	119.00	9.57	0.468	567	0.05	-0.69	4
Yugoslavia	4.86	0.48	--	--	--	-0.80	0
Zambia	0.00	0.00	0.427	837	10.94	-0.97	0
Zimbabwe	5.05	0.47	0.554	2 336	17.51	-1.17	0

TABLE 1 DISASTER RISK INDEX SUMMARY TABLE, 1980 - 2000

	Number of people killed per year	Average number of people killed per million inhabitants	Average HDI 1980-2000	Gross Domestic Product Purchasing Power Parity, 1990	Percentage of population infected by HIV/AIDS virus, 2001	Control of corruption 2002	Average percentage of people affected by conflicts per year, 1980 - 2000
Tributarians Territories (alphabetical order)	Killed per Year	Killed per million	HDI_{kv}*	GDPcap (ppp)	%	Corruption	%population
American Samoa	1.19	27.78	--	--	--	--	0
Anguilla	0.00	0.00	--	--	--	--	0
Bermuda	0.00	0.00	--	--	--	1.29	0
British Virgin Islands	0.00	0.00	--	--	--	--	0
Cocos (Keeling) Islands	--	--	--	--	--	--	0
Cook Islands	1.19	65.09	--	--	--	--	0
French Guiana	0.00	0.00	--	--	--	--	0
French Polynesia	0.33	2.02	--	18 594	--	--	0
Guadeloupe	0.43	1.09	--	--	--	--	0
Guam	0.05	0.34	--	--	--	--	0
Macau, China	0.00	0.00	--	14 080	--	-0.07	0
Martinique	0.48	1.33	--	--	--	--	0
Montserrat	0.52	48.73	--	--	--	--	0
New Caledonia	0.29	1.76	--	19 745	--	--	0
Netherlands Antilles	0.10	0.49	--	--	--	--	0
Niue	0.00	0.00	--	--	--	--	0
Puerto Rico	25.81	7.22	--	--	--	1.19	0
Reunion	2.90	4.87	--	--	--	--	0
Tokelau	0.00	0.00	--	--	--	--	0
Turks and Caicos Islands	0.00	0.00	--	--	--	--	0
United States Virgin Islands	0.52	4.49	--	--	--	--	0
Wallis and Futuna	0.29	21.18	--	--	--	--	0

Source:

Columns 1 and 2: EM-DAT: The OFDA/CRED International Disaster Database

Column 3: calculated by UNDP/BCPR and UNEP/GRID-Geneva for this report. For details, see note below

Column 4: calculated by UNDP/BCPR and UNEP/GRID-Geneva from World Development Indicators (World Bank), "ppp", purchasing power parity

Column 5: UNAIDS "Report on the global HIV/AIDS epidemic July 2002. For details, see http://www.unaids.org/barcelona/presskit/barcelona%20report/contents.html

Column 6: World Bank estimates (From +2.5 maximum control of corruption to -2.5 minimum control of corruption).

World Bank Governance Matters III: updated indicators for 1996-2002. For more details see http://www.worldbank.org/wbi/governance

Column 7: Armed Conflict 1946-2001, International Peace Research Institute, Oslo (PRIO), For more detailed information see http://www.prio.no/cwp/armedconflict

***Note:** Human Development Index has been adjusted as follows: HDI_{kv} = (Sum Ki)HDI(i)/(Sum Ki)

Where "K" is the number of people killed by this disaster, "i" is the year and HDIi is the HDI linearly extrapolated from the standard 5-year interval HDI.

TABLE 2 DISASTER RISK FOR DROUGHTS, 1980 - 2000

	Average number of events per year	Number of people killed per year	Average number of people killed per million inhabitants	Average physical exposure per year	Physical exposure in percentage of population	Relative Vulnerability	Percentage of total population with access to safe water
Country Name	Event per year	Killed per year	Killed per million	People per year	%	Killed per million exposed	%
Democratic People's Republic of Korea	0.10	12 857.14	579.43	763174	3.44	16 846.94	--
Mozambique	0.43	4 764.29	357.06	878 635	6.58	5 422.37	60.0
Ethiopia	0.57	14 303.19	286.24	2 756 273	5.52	5 189.32	23.0
Sudan	0.48	7 142.86	294.05	2 478 870	10.20	2 881.50	71.0
Mauritania	0.33	106.81	57.86	172 159	9.33	620.41	37.0
Chad	0.33	142.86	27.87	514 050	10.03	277.91	27.0
Somalia	0.24	29.57	4.14	726 181	10.17	40.72	--
Madagascar	0.24	9.52	0.78	324 977	2.66	29.31	45.5
Uganda	0.29	5.48	0.29	242 373	1.30	22.59	47.0
Papua New Guinea	0.14	4.67	1.16	436 919	10.83	10.68	42.0
China	0.86	161.90	0.14	26 855 212	2.31	6.03	73.0
Guinea	0.14	0.57	0.10	161 647	2.73	3.54	46.5
Kenya	0.29	4.05	0.16	1 219 322	4.97	3.32	44.5
Indonesia	0.29	60.29	0.34	29 982 870	16.77	2.01	72.5
Burundi	0.10	0.29	0.05	269 943	4.28	1.06	65.0
Pakistan	0.05	6.81	0.05	9 811 893	6.95	0.69	86.0
India	0.38	19.52	0.02	3 3701 757	3.91	0.58	83.0
Brazil	0.43	0.95	0.01	10 345 734	6.89	0.09	84.5
Philippines	0.24	0.38	0.01	8 240 940	13.39	0.05	87.0

Source: Columns 1, 2 and 3: EM-DAT: The OFDA/CRED International Disaster Database; Columns 4, 5, and 6 calculated by the IRI of Columbia University, UNDP/BCPR and UNEP/GRID-Geneva for this report. For details, see technical annex; Column 7: UNEP/GRID-Geneva, calculated from WHO figures. For more details see http://geodata.grid.unep.ch

TABLE 3 DISASTER RISK FOR EARTHQUAKES, 1980 - 2000

Country Name	Average number of events per year*	Number of people killed per year	Average number of people killed per million inhabitants	Average physical exposure per year	Physical exposure in percentage of population	Relative Vulnerability	Percentage of Urban growth (as average for 3-year period)
	Event per year	Killed per Year	Killed per million	People per year	%	Killed per million exposed	%
Armenia	0.05	1 190.48	343.96	155 560	4.49	7 652.82	0.03
Iran (Islamic Republic of)	1.43	2 250.81	38.68	2 094 097	3.60	1 074.84	0.15
Yemen	0.10	72.29	6.90	95 423	0.91	757.53	0.24
Turkey	0.76	949.86	15.58	2 745 757	4.50	345.94	0.15
Afghanistan	0.81	399.95	2480	1 749 097	0.11	228.1	0.13
India	0.67	576.52	0.73	2 730 309	0.35	211.16	0.09
Italy	0.52	225.71	3.98	1 288 265	2.27	175.21	0.00
Russian Federation	0.29	95.29	0.65	658 876	0.45	144.62	0.03
Algeria	0.38	137.19	5.79	1 252 109	5.28	109.57	0.14
Mexico	0.76	427.24	5.05	4 145 529	4.90	103.06	0.08
Nepal	0.10	38.52	2.42	512 716	3.22	75.14	0.19
Georgia	0.14	13.29	2.44	286 210	5.25	46.42	0.04
El Salvador	0.10	53.33	11.23	1 272 919	26.81	41.90	0.07
Pakistan	0.62	30.95	0.30	793 845	0.77	38.99	0.14
Egypt	0.10	27.19	0.45	834 006	1.38	32.60	0.08
Colombia	0.48	85.05	2.34	2 663 322	7.33	31.93	0.09
Bolivia	0.14	5.95	0.86	186 491	2.69	31.92	0.13
Australia	0.14	1.10	0.07	40 727	0.25	26.89	0.04
China	2.10	92.24	0.08	3 493 705	0.30	26.40	0.13
South Africa	0.14	1.62	0.05	82 467	0.25	19.63	0.08
Ecuador	0.43	28.33	2.75	1 542 854	14.97	18.36	0.12
Panama	0.05	1.43	0.58	95 128	3.89	15.02	0.08
Kyrgyzstan	0.10	2.76	0.62	227 769	5.10	12.13	0.04
Indonesia	1.62	193.24	1.04	16 301 764	8.80	11.85	0.15
Venezuela	0.14	4.62	0.25	435 949	2.34	10.60	0.09
Japan	1.14	281.29	2.31	30 855 862	25.39	9.12	0.02
Philippines	0.57	120.57	2.03	16 228 511	27.30	7.43	0.14
Peru	0.62	13.00	0.62	1 844 498	8.81	7.05	0.08
Greece	0.62	11.29	1.11	1 621 341	15.89	6.96	0.03
Nicaragua	0.14	8.86	2.05	1 515 588	35.13	5.84	0.11
Uganda	0.14	0.33	0.02	62 081	0.35	5.37	0.16
Azerbaijan	0.14	1.52	0.19	439 907	5.51	3.46	0.04
Malawi	0.05	0.43	0.05	13 0484	1.44	3.28	0.18
Brazil	0.05	0.05	0.00	14 592	0.01	3.26	0.09
Costa Rica	0.33	2.52	0.85	868 232	29.33	2.91	0.11
Chile	0.24	9.48	0.73	4 465 047	34.34	2.12	0.06
Papua New Guinea	0.33	3.10	0.83	1 645 460	44.19	1.88	0.12
Cyprus	0.05	0.10	0.13	58 652	7.89	1.62	0.07
Bangladesh	0.19	1.38	0.01	925 173	0.73	1.49	0.17
Kazakhstan	0.10	0.05	0.00	39 696	0.24	1.20	0.04
United States of America	0.48	6.52	0.03	6 745 799	2.61	0.97	0.04
Uzbekistan	0.10	0.43	0.02	477 708	2.44	0.90	0.05
Belgium	0.10	0.10	0.01	108 164	1.09	0.88	0.01
United Republic of Tanzania	0.05	0.05	0.00	64 343	0.18	0.74	0.22
Guatemala	0.24	1.71	0.20	2 671 752	30.85	0.64	0.10
Argentina	0.05	0.29	0.01	515 880	1.70	0.55	0.06
Romania	0.14	0.52	0.02	1 007 506	4.37	0.52	0.03
Albania	0.14	0.05	0.02	155 688	5.41	0.31	0.07
New Zealand	0.05	0.05	0.01	239 427	7.28	0.20	0.03
Germany	**0.05**	**0.05**	**0.00**	**357 730**	**0.44**	**0.13**	**0.02**

Source: Columns 1, 2 and 3: EM-DAT: The OFDA/CRED International Disaster Database; Columns 4, 5, and 6: calculated by UNDP/BCPR and UNEP/GRID-Geneva for this report. For details, see technical annex; Column 7: UNEP/GRID-Geneva, calculated from UNDESA: UN Dep. Of Economic and Social Affairs/Population Division.
*Note: These include events equal or greater than a magnitude of 5.5 on the Richter scale.

TABLE 4 DISASTER RISK FOR FLOODS, 1980 - 2000

Country Name	Average number of events per year	Number of people killed per year	Average number of people killed per million inhabitants	Average physical exposure per year	Physical exposure in percentage of population	Relative Vulnerability	Density of population (living in the watershed exposed to flood)	Gross Domestic Product, per capita, ppp)
	Event per year	Killed per Year	Killed per million	People per year	%	Killed per million exposed	Inhab. per km²	
Venezuela	0.66	1 439.62	68.30	3 136 576	14.88	458.98	0.26	5 081
Somalia	0.52	117.62	15.38	693 220	0.09	169.67	0.11	--
Morocco	0.33	39.62	1.40	395 262	1.40	100.23	0.95	2 650
Papua New Guinea	0.24	2.76	0.72	37 288	0.98	74.07	0.04	1 898
Egypt	0.14	28.95	0.48	406 277	0.68	71.26	1.44	2 287
Botswana	0.14	1.48	1.07	23 330	1.69	63.28	0.06	4 734
Yemen	0.52	46.71	3.65	938 991	7.34	49.75	0.48	746
Zimbabwe	0.10	5.05	0.41	150 152	1.21	33.62	0.31	2 158
Fiji	0.14	1.57	2.10	50 037	6.67	31.41	16.71	3 721
South Africa	0.67	54.71	1.38	1 828 614	4.61	29.92	0.12	7 899
Mozambique	0.33	41.33	2.66	1 471 643	9.46	28.09	0.23	556
Malawi	0.43	23.33	2.36	899 039	9.11	25.95	3.12	459
Ghana	0.19	9.95	0.60	387 393	2.33	25.69	1.02	1 391
Georgia	0.14	4.81	0.90	189 551	3.54	25.37	14.27	2 353
Guatemala	0.43	38.24	4.02	1 541 278	16.18	24.81	3.10	2 885
Mexico	1.10	121.19	1.41	4 931 631	5.75	24.57	0.17	6 453
Gambia	0.10	2.52	2.09	105 270	8.70	23.97	31.44	1 340
El Salvador	0.33	26.76	4.92	1 239 827	22.80	21.59	29.00	3 159
Ethiopia	1.00	27.14	0.50	1 354 486	2.51	20.04	0.15	525
Honduras	0.62	30.62	6.09	1 762 646	35.07	17.37	2.50	2 043
Algeria	0.71	13.33	0.50	796 804	3.01	16.73	0.15	4 394
Tunisia	0.14	8.43	1.13	533 010	7.12	15.81	1.96	4 090
United Republic of Tanzania	0.71	22.00	0.77	1 414 090	4.93	15.56	0.21	453
Angola	0.24	1.38	0.11	93 118	0.75	14.83	0.16	1 811
Mali	0.29	1.81	0.18	124 529	1.23	14.53	0.10	576
Saudi Arabia	0.05	1.52	0.12	117 250	0.96	13.00	0.11	10 201
Viet Nam	1.00	137.90	1.98	10 896 441	15.64	12.66	2.63	1 427
Uganda	0.14	7.05	0.36	570 394	2.88	12.36	5.60	794
Burkina Faso	0.24	2.10	0.23	174 801	1.93	11.99	0.68	713
Nepal	0.90	199.38	10.92	17 156 240	93.97	11.62	13.00	927
China	5.57	1 490.57	1.32	147 884 196	13.06	10.08	0.14	1 741
Kenya	0.24	12.86	0.50	1 370 897	5.33	9.38	1.13	878
Thailand	1.33	78.52	1.37	8 376 157	14.63	9.37	1.12	3952
Bangladesh	2.00	461.95	4.11	51 929 673	46.19	8.90	19.93	1 014
Turkey	0.67	20.90	0.36	2 419 658	4.19	8.64	0.64	4 681
Sierra Leone	0.05	0.57	0.14	66 651	1.63	8.57	9.58	665
Portugal	0.19	3.33	0.34	389 574	3.92	8.56	23.43	10 920
Cambodia	0.29	48.52	4.08	5 678 181	47.72	8.55	4.21	1 096
India	3.86	1 313.24	1.55	157 540 274	18.57	8.34	0.58	1 424
Spain	0.52	8.38	0.21	1 025 097	2.63	8.18	0.65	12 301
Philippines	1.76	75.71	1.22	9 314 934	14.98	8.13	5.73	3 191
Peru	1.10	97.62	4.56	13 072 909	61.09	7.47	0.49	3 843
Sri Lanka	1.29	27.62	1.62	4 072 445	23.90	6.78	13.39	2 142
Republic of Korea	0.71	51.95	1.19	7 721 548	17.63	6.73	20.03	9 243
Chile	0.57	16.48	1.21	2 547 463	18.77	6.47	0.29	5 512
Chad	0.29	4.00	0.63	671 973	10.53	5.95	0.09	705
Rwanda	0.05	2.29	0.34	391 316	5.84	5.84	40.32	952
Romania	0.43	9.24	0.41	1 633 626	7.23	5.65	1.78	5 955
Niger	0.29	4.57	0.47	810 946	8.41	5.64	0.26	719
Moldova, Republic of	0.14	2.67	0.62	476 922	11.03	5.59	61.78	2 876
Jamaica	0.24	3.43	1.45	655 203	27.75	5.23	216.78	3 124
Haiti	0.81	11.90	1.72	2 565 270	37.11	4.64	59.27	1 449
Slovakia	0.10	2.67	0.49	593 686	11.01	4.49	23.06	7 905

TABLE 4 DISASTER RISK FOR FLOODS, 1980 - 2000

	Average number of events per year	Number of people killed per year	Average number of people killed per million inhabitants	Average physical exposure per year	Physical exposure in percentage of population	Relative Vulnerability	Density of population (living in the watershed exposed to flood)	Gross Domestic Product, per capita, ppp)
Country Name	Event per year	Killed per Year	Killed per million	People per year	%	Killed per million exposed	Inhab. per km²	
Cote d'Ivoire	0.10	1.33	0.10	297 627	2.21	4.48	3.48	1413
Nicaragua	0.24	2.52	0.60	569 095	13.44	4.43	1.46	2146
Colombia	1.14	47.90	1.34	10 901 999	30.50	4.39	0.30	4625
Benin	0.48	4.67	0.91	1 092 463	21.33	4.27	4.64	736
Panama	0.29	0.81	0.32	190 108	7.48	4.26	2.21	4352
Albania	0.19	0.71	0.22	169 207	5.29	4.22	24.40	2755
Italy	0.57	14.00	0.24	3 371 565	5.89	4.15	3.42	16619
Pakistan	0.95	200.38	1.77	48 751 464	42.97	4.11	1.86	1308
Australia	1.10	4.43	0.26	1 094 340	6.37	4.05	0.02	17293
Jordan	0.10	0.81	0.26	204 262	6.46	3.96	11.32	3498
Burundi	0.10	0.57	0.10	157 991	2.66	3.62	44.81	610
Russian Federation	1.33	9.24	0.06	2 711 300	1.85	3.41	0.01	8179
Brazil	2.19	99.33	0.67	29 369 028	19.79	3.38	0.06	5623
Iran (Islamic Republic of)	1.90	131.19	2.20	39 127 510	65.55	3.35	0.26	3932
Costa Rica	0.38	1.67	0.51	536 809	16.36	3.10	4.04	5415
Malaysia	0.43	4.43	0.24	1 432 155	7.61	3.09	1.15	5380
Ecuador	0.38	30.62	2.92	10 184 870	97.12	3.01	2.89	2695
Nigeria	0.62	12.67	0.12	4 251 902	3.92	2.98	0.87	783
Japan	0.62	30.71	0.25	10 975 689	8.90	2.80	8.50	18629
Cameroon	0.24	1.76	0.13	632 109	4.84	2.79	1.55	1521
Bolivia	0.48	14.48	2.27	5 933 207	93.00	2.44	0.60	1868
Indonesia	2.48	120.29	0.67	49 405 779	27.39	2.43	0.55	1964
Czech Republic	0.05	1.38	0.13	587 703	5.70	2.35	15.99	12296
Ukraine	0.29	3.00	0.06	1 324 692	2.58	2.26	1.31	5178
Poland	0.24	2.95	0.08	1 430 858	3.83	2.06	1.51	6939
United States of America	3.48	24.19	0.09	11 912 776	4.56	2.03	0.03	22494
France	1.10	5.29	0.09	2 850 310	4.96	1.85	0.99	17072
Canada	0.52	1.52	0.05	876 436	3.14	1.74	0.03	19456
Greece	0.19	1.19	0.11	844 233	8.00	1.41	13.90	11148
Bhutan	0.10	10.57	5.44	8 529 300	439.23	1.24	63.42	336
Argentina	1.19	11.14	0.34	9 899 475	30.24	1.13	0.14	9310
Paraguay	0.38	3.62	0.85	3 268 907	76.69	1.11	0.92	3841
Lao People's Democratic Republic	0.43	3.29	0.75	3 190 331	72.86	1.03	1.22	918
Austria	0.29	0.90	0.12	932 211	12.14	0.97	7.74	18289
Azerbaijan	0.19	0.76	0.10	832 565	10.78	0.92	4.83	3670
Dominican Republic	0.29	3.00	0.42	3 388 907	47.79	0.89	17.69	3700
Israel	0.10	0.52	0.09	880 972	15.42	0.59	66.76	14084
United Kingdom of Great Britain & Northern Ireland	0.43	0.48	0.01	2 192 765	3.72	0.22	8.58	18738
Germany	0.38	1.00	0.01	4 612 953	5.73	0.22	2.54	21848

Source: Columns 1, 2 and 3: EM-DAT: The OFDA/CRED International Disaster Database; Columns 4, 5, and 6: calculated by UNDP/BCPR and UNEP/GRID-Geneva for this report. For details, see technical annex; Column 7: UNEP/GRID-Geneva, calculated from UNEP/GRID-Geneva spatial modelling based on CIESIN population data. For more details see http://geodata.grid.unep.ch; Column 8: UNEP/GRID-Geneva from World Development Indicators (World Bank), "ppp", purchasing power parity.

TABLE 5 DISASTER RISK FOR TROPICAL CYCLONES, 1980 - 2000

	Average number of events per year	Number of people killed per year	Number of people killed per million inhabitants	Average physical exposure per year	Physical exposure in percentage of population	Relative Vulnerability	Percentage of Arable Land	Average HDI 1980-2000
Country Name	Event per year	Killed per Year	Killed per million	People per year	%	Killed per million exposed	%	HDI_{av}*
Honduras	0.19	702.29	139.65	2 185 215	43.45	321.38	16.44	0.61
Nicaragua	0.33	162.57	37.39	804 228	18.50	202.15	17.92	0.60
Cape Verde	0.10	1.52	5.07	18 402	6.12	82.80	10.21	0.65
Swaziland	0.05	2.52	4.04	34 728	5.56	72.67	10.26	0.59
Bangladesh	3.43	7 467.62	64.02	135 835 143	116.45	54.98	67.77	0.41
El Salvador	0.19	23.43	3.90	847 932	14.12	27.63	38.56	0.64
Comoros	0.19	2.81	5.97	137 528	29.25	20.43	49.81	0.50
Haiti	0.29	81.24	11.63	6 269 306	89.77	12.96	32.82	0.45
Pakistan	0.62	53.90	0.46	4 697 462	4.04	11.48	27.40	0.44
Malaysia	0.10	12.86	0.60	1 368 871	6.41	9.39	19.91	0.72
Papua New Guinea	0.10	2.24	0.52	289 367	6.76	7.73	1.32	0.49
Fiji	0.67	5.71	7.99	1 012 072	141.57	5.65	12.87	0.72
Viet Nam	2.24	435.24	6.40	77 521 410	114.01	5.61	20.60	0.63
Mozambique	0.33	22.10	1.41	4 698 084	29.88	4.70	4.17	0.31
Madagascar	0.71	48.81	3.87	11 638 792	92.36	4.19	5.27	0.44
Belize	0.10	0.67	3.01	176 043	79.48	3.79	3.05	0.75
Costa Rica	0.19	4.29	1.22	1 196 901	34.15	3.58	10.04	0.79
Philippines	5.57	863.19	14.35	259 304 805	430.94	3.33	32.99	0.71
Guatemala	0.05	18.29	1.69	6 226 716	57.65	2.94	16.87	0.58
India	2.76	1 022.52	1.24	352 431 552	42.75	2.90	56.94	0.51
Dominican Republic	0.38	19.19	2.68	6 889 529	96.30	2.79	30.72	0.68
United States of America	12.14	222.86	0.86	89 407 185	34.41	2.49	20.23	0.91
Thailand	0.71	30.24	0.54	12 739 238	22.84	2.37	38.38	0.71
Republic of Korea	1.00	71.52	1.67	37 649 377	87.85	1.90	20.98	0.81
Jamaica	0.24	3.14	1.34	2 169 085	92.57	1.45	22.52	0.72
Colombia	0.14	1.48	0.05	1 180 056	3.68	1.25	4.66	0.72
Mexico	1.57	80.76	0.93	65 081 375	74.78	1.24	13.64	0.76
Australia	2.38	4.43	0.26	3 666 088	21.72	1.21	6.26	0.90
Venezuela	0.10	5.14	0.26	6 534 046	33.13	0.79	4.20	0.75
China	6.90	428.38	0.37	579 217 240	49.51	0.74	13.50	0.63
Lao People's Democratic Republic	0.19	2.67	0.60	4 554 774	102.72	0.59	3.75	0.42
New Zealand	0.29	0.48	0.13	848 108	23.87	0.56	13.03	0.88
Japan	1.95	39.29	0.32	226 166 900	184.04	0.17	14.26	0.90

Source: Columns 1, 2 and 3: EM-DAT: The OFDA/CRED International Disaster Database; Columns 4, 5, and 6: calculated by UNDP/BCPR and UNEP/GRID-Geneva for this report. For details, see technical annex; Column 7: UNEP/GRID-Geneva, calculated from FAOSTAT; Column 8: Calculated by UNEP/GRID-Geneva, for details see note below

*Note: Human Development Index has been adjusted as follows: HDI_{av} = (Sum KiHDIi)/(Sum Ki)
Where "K" is the number of people killed by this disaster, "i" is the year and HDIi is the HDI linearly extrapolated from the standard 5-year interval HDI.