locally between different types of volcanic hazard. Data for such a task exists and could be compiled into an international database.

The DRI tests vulnerability indicators from available global datasets

The DRI has run statistical regression analysis comparing some 26 socio-economic and environmental variables with risk levels in order to identify possible indicators of vulnerability.

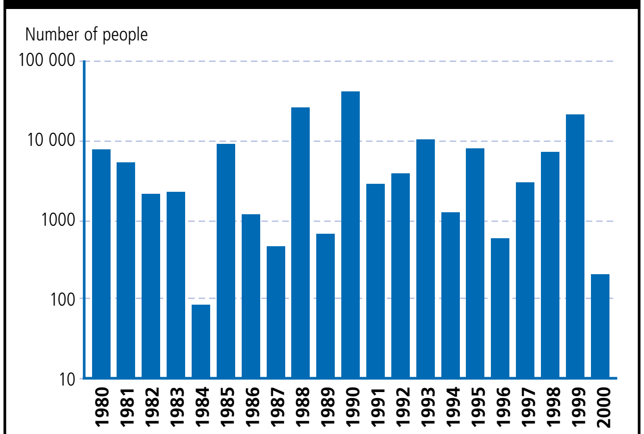
Clearly the variables that could be tested are those that were available in global datasets. This implies that there may be other variables that potentially might help build a better correlation with risk, but for which no global datasets were available at the time of production of the DRI. The choice of vulnerability indicators presented in the DRI, therefore, is limited by available data. It is hoped that in the future more direct indicators of national vulnerability might be available, for example, soil types or the proportion of earthquake resistant buildings per country for earthquake hazard.

The logarithmic base of the model can highlight long-term trends, but does not allow predictive casualties to be made. Small differences in the vulnerability indicator figures can mask major changes in disaster risk.

The DRI does not include indicators on disaster risk management and reduction

In terms of assisting the advocacy purposes of the DRI, an ongoing aim is to generate a disaster risk reduction component. National change over time or comparison between countries operating alternative

FIGURE 2.2 PEOPLE KILLED BY EARTHQUAKES, 1980-2000



Source: The EM-DAT OFDA/CRED International Disaster Database

risk management strategies can be used as an initial level of analysis of the comparative effectiveness of competing risk reduction strategies (including a do-nothing option). But a dedicated comparative index built up of components found to indicate risk reduction would be a clearer tool. Unfortunately, conceptual work remains to be done in identifying key indicators for multiple hazard types operating in a range of socio-political contexts.

2.2 Hazard Specific Risk Profiles

2.2.1 Earthquake hazard

A total of 158,551 deaths were associated with earthquakes around the world between 1980-2000 (see Figure 2.2).

Iran has the highest toll of death for this period, with 47,267 people killed in earthquakes.

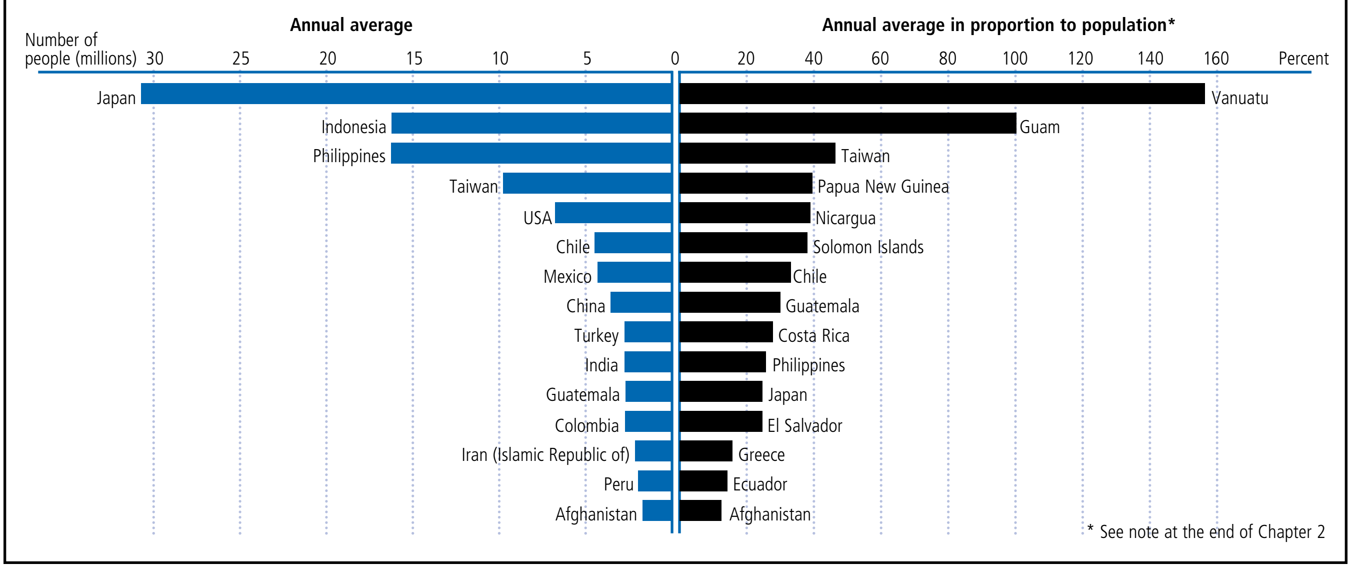
About 130 million people were found to be exposed on average every year to earthquake risk as the defined in this Report.

The left hand axis of Figure 2.3 shows the fifteen countries with the largest absolute populations exposed to earthquake hazard. Populous Asian states (Japan, Indonesia and the Philippines) top the list with the Americas (USA, Chile, Mexico), Turkey and India also included. The right hand axis displays the fifteen countries with the highest proportion of their populations exposed to earthquake hazard. Smaller island states (Vanuatu, Guam, Papua New Guinea) and Central American states (Nicaragua, Guatemala) top the list.

Comparing the size of exposed populations with the number of recorded deaths to earthquake hazard is used as a measure of relative vulnerability in Figure 2.4. Those states closest to the top left-hand corner of the graph show highest relative vulnerability.

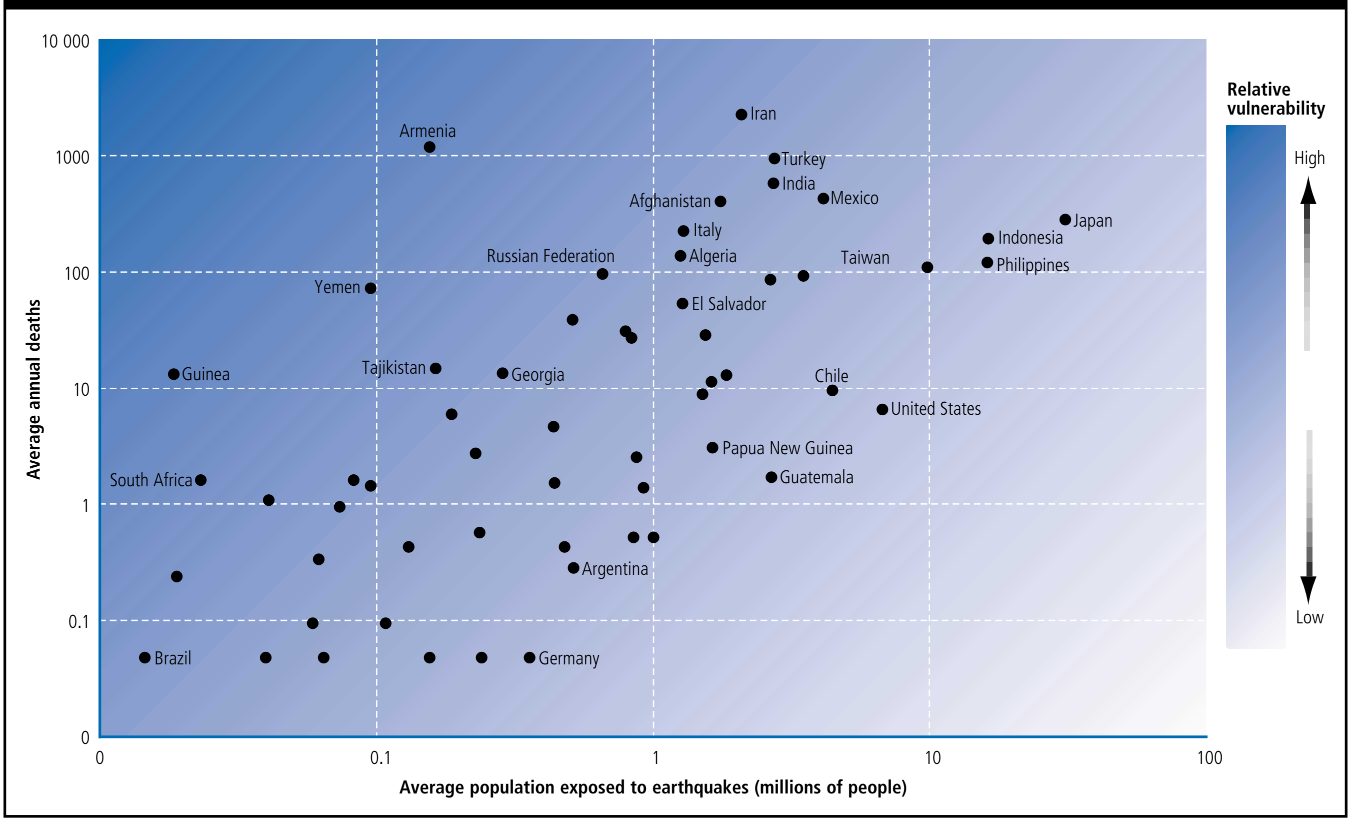
The graph represents relative earthquake vulnerability between 1980 and 2000 only. Armenia stands out as being particularly vulnerable to earthquakes due to a single major catastrophic event that occurred during the reporting period. Similarly, earthquakes are rare in Guinea, however a significant event occurred in the reporting period. In contrast, Guatemala appears far less vulnerable because the catastrophic earthquake of

FIGURE 2.3 PHYSICAL EXPOSURE TO EARTHQUAKES, 1980–2000



Source: UNDP/BCPR; UNEP/GRID-Geneva

FIGURE 2.4 RELATIVE VULNERABILITY FOR EARTHQUAKES, 1980–2000

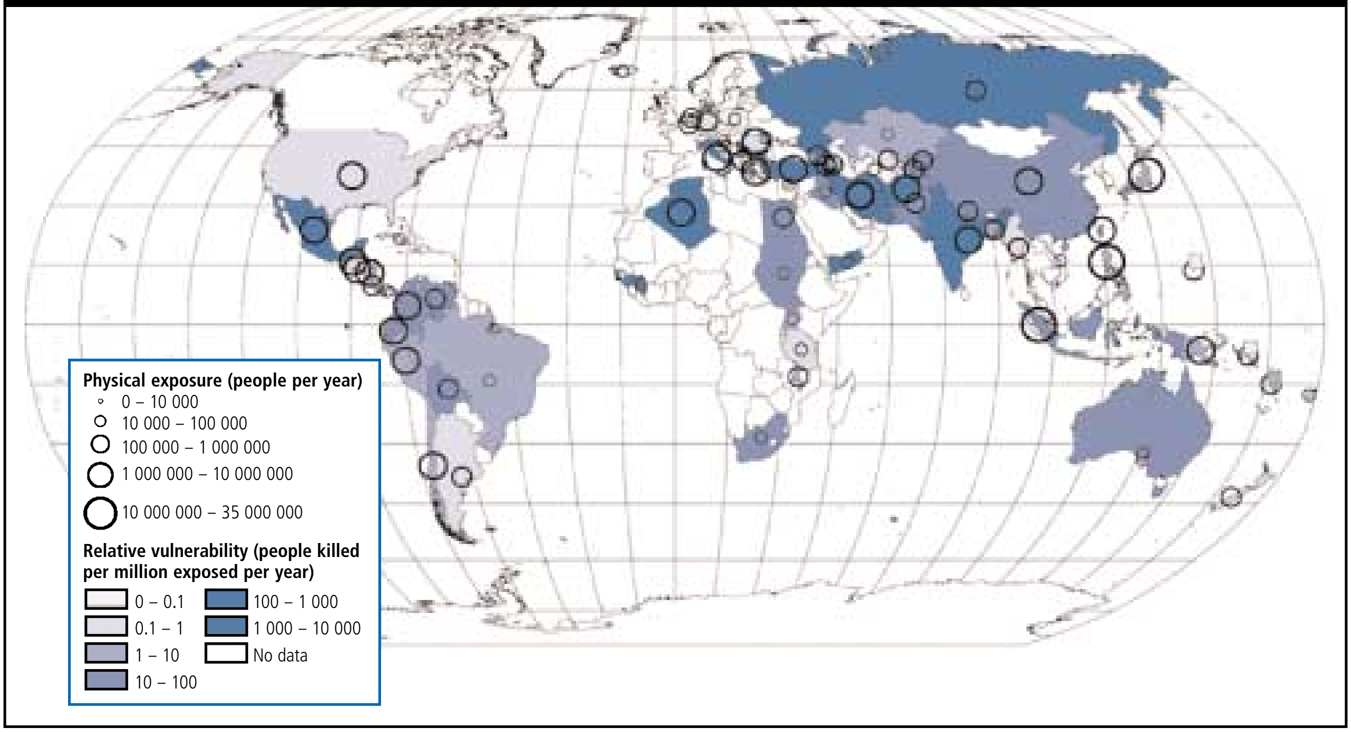


Source: The EM-DAT OFDA/CRED International Disaster Database and UNEP/GRID-Geneva

1976 occurred outside of the reporting period. China and Peru are other countries that experienced very high mortality in catastrophic earthquakes during the 1970s and therefore outside of the reporting period. The analysis, however, does show countries, such as the Islamic Republic of Iran, Afghanistan and India, which do experience frequent earthquakes suffering proportionally far higher loss of life than others, such as Chile or the United States of America.

The tight fit of countries in Figure 2.4 along an axis from the bottom left to the top right-hand corner indicates intuitively a strong correlation between the number of deaths and physical exposure. In other words,

FIGURE 2.5 PHYSICAL EXPOSURE AND RELATIVE VULNERABILITY TO EARTHQUAKES, 1980–2000



Source: Université Catholique de Louvain: The EM-DAT The OFDA/CRED International Disaster Database (victims); Council of the National Seismic System (CNSS): Earthquake Catalog (earthquakes extent); CIESIN, IFPRI, WRI: Gridded Population of the World (GPW), Version 2 (population); Compilation and computation by UNEP/GRID-Geneva

the more people living in areas exposed to earthquake events, the higher the risk of death.

Regression analysis of vulnerability indicators showed that statistically, physical exposure and the rate of urban growth acted together in being associated with the risk of death to earthquake. In other words, the risk of dying in an earthquake was greater in countries with rapid urban growth.

Urban growth does not *explain* human vulnerability to earthquakes *per se.* Rather it is particular processes and factors of urban change that characterise rapidly urbanising countries that increase human vulnerability to earthquakes. These processes and factors will vary considerably from context to context. The earthquake disasters of Turkey in 1999 and Algeria in 2003 highlighted the lack of enforcement of building regulations as a key factor in generating physical vulnerability (see Box 3.1). A study of earthquake vulnerability in Lima, Peru showed that a process of deterioration and overcrowding of inner city rental housing was the key process associated with urban growth that was generating earthquake vulnerability.[3] In the 2001 Gujarat earthquake in India, it was non-earthquake resistant structures in both rural and urban housing that proved to be a key vulnerability factor. In urban areas, the high density of dwellings increased fatalities.[4]

The fact that some countries with high urban growth rates have low relative vulnerability means that it is impossible to generalise. However, common to all the examples above is the fact that in many rapidly growing cities, earthquake risk considerations have not been factored into the building and planning process. In general, city governments have not been capable of regulating either building or settlement in a way that reduces risks. This is a key issue that will be explored in greater depth in Chapter 3.

A final representation of earthquake risk is shown in the World Map in Figure 2.5. Again, urban countries appear most at risk. (See the Appendix for data on individual countries.)

2.2.2 Tropical cyclone hazard

The term tropical cyclone used in this report includes tropical storms, hurricanes (alternatively termed typhoons, tropical cyclones or severe cyclonic storms), and super typhoons. Up to 119 million people were found to be exposed on average every year to tropical cyclone hazard and some people experienced an average of more than four events every year. As a result, a total of 251,384 deaths have been associated with tropical cyclones worldwide, 1980-2000 (Figure 2.6). Bangladesh accounts for more than 60 percent of the registered deaths in this period while the Philippines show the highest frequency of tropical cyclones with reported deaths.

Hazard zones for tropical cyclones were based on data from the Carbon Dioxide Information Analysis (CDIAC) of the US government.

A total of 84 countries distributed over the tropics presented different levels of physical exposure to tropical cyclones (Figure 2.7). Those countries with the largest exposed populations have highly populated coastal areas and especially densely populated deltas (China, India, the Philippines, Japan, Bangladesh). Expressing exposure as a proportion of national population flagged island states and territories (Guam, the British Virgin Islands, Vanuatu, Mauritius) and the Philippines (a collection of islands).

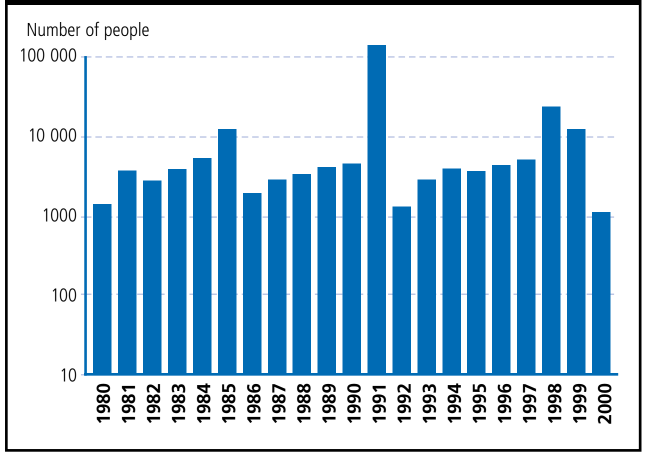
Comparing the size of exposed populations with the number of recorded deaths to tropical cyclones is used as a measure of relative vulnerability to tropical cyclone death in Figure 2.8. Those states closest to the top left-hand corner of the graph show highest relative vulnerability.

A very large proportion of the population of Bangladesh is exposed to tropical cyclones, particularly the heavily populated rural communities along the fertile delta at the confined head of the Bay of Bengal. The large number of recorded deaths shows that in this case high vulnerability accompanies high physical exposure.

Honduras and Nicaragua, while not among the countries with the highest physical exposure, appear as the most vulnerable countries in the period 1980-2000. This reflects the extraordinary magnitude and duration and the devastating human impact of Hurricane Mitch, which occurred in 1998.

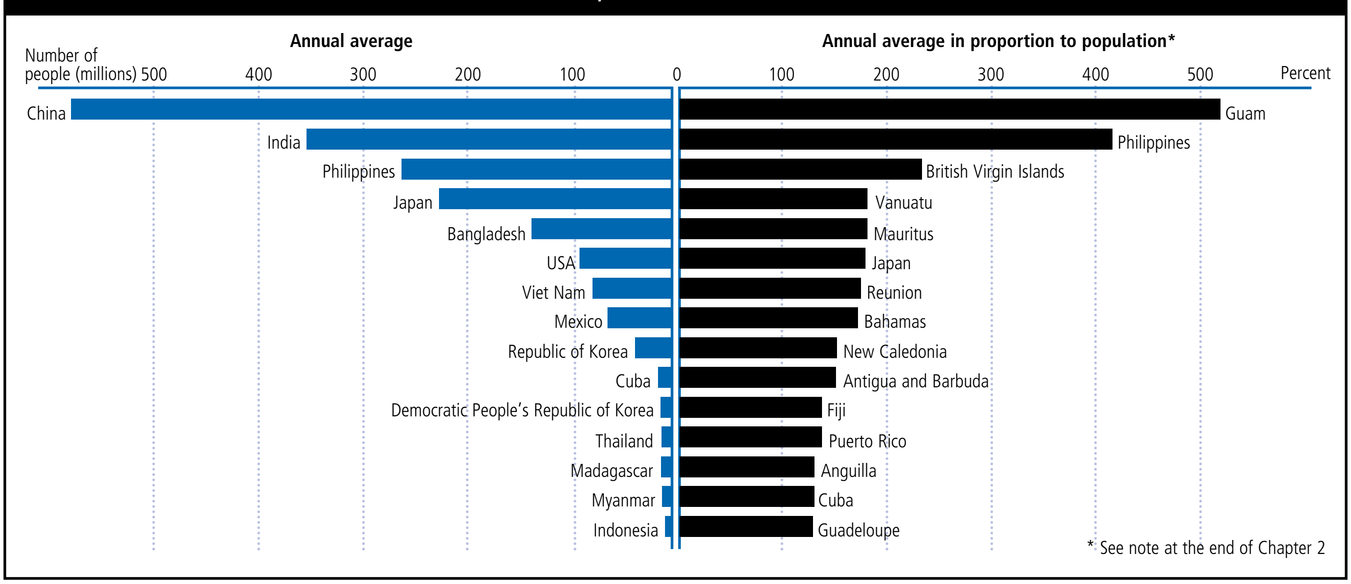
The complexity of the hazard events associated with tropical cyclones illustrates another of the limitations of the DRI model mentioned in section 2.1.2. Much

FIGURE 2.6 PEOPLE KILLED BY TROPICAL CYCLONES, 1980-2000



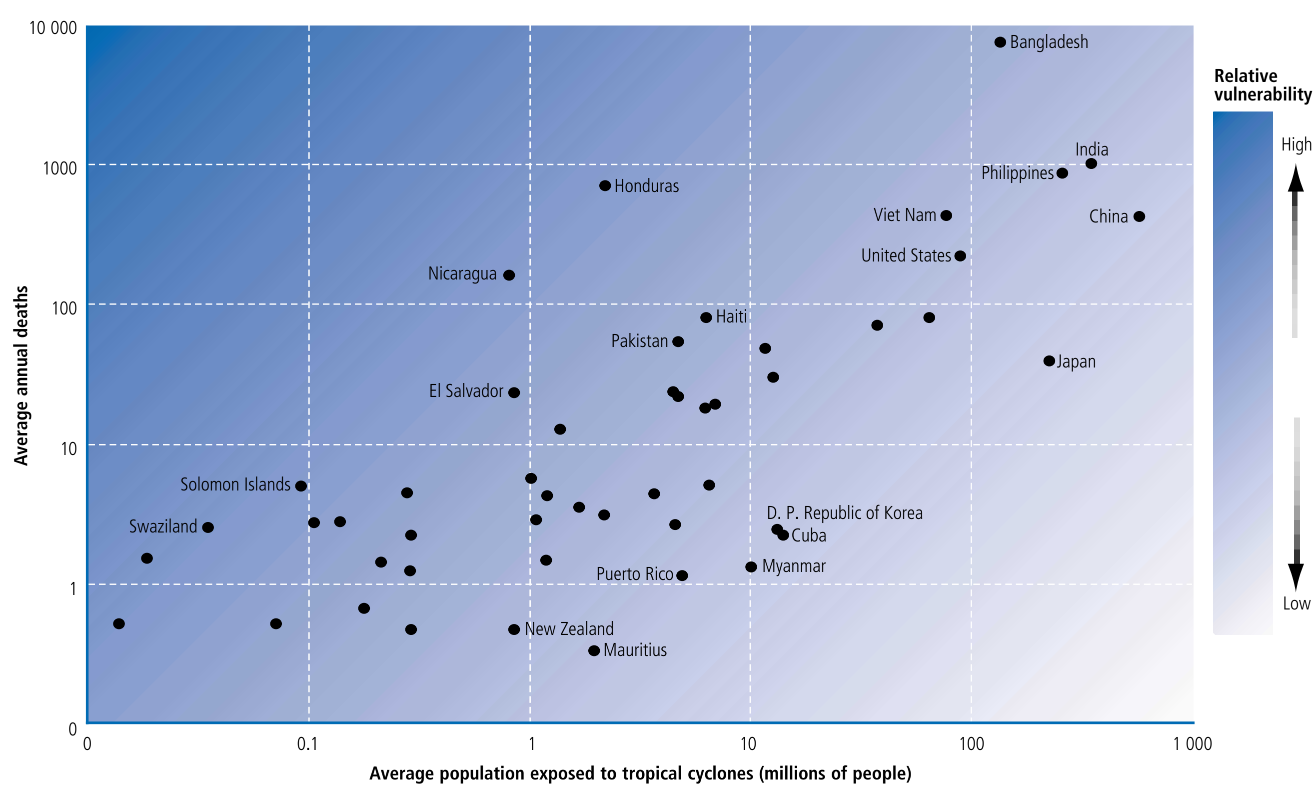
Source: The EM-DAT OFDA/CRED International Disaster Database

FIGURE 2.7 PHYSICAL EXPOSURE TO TROPICAL CYCLONES, 1980–2000



Source: UNDP/BCPR; UNEP/GRID-Geneva

FIGURE 2.8 RELATIVE VULNERABILITY FOR TROPICAL CYCLONES, 1980–2000

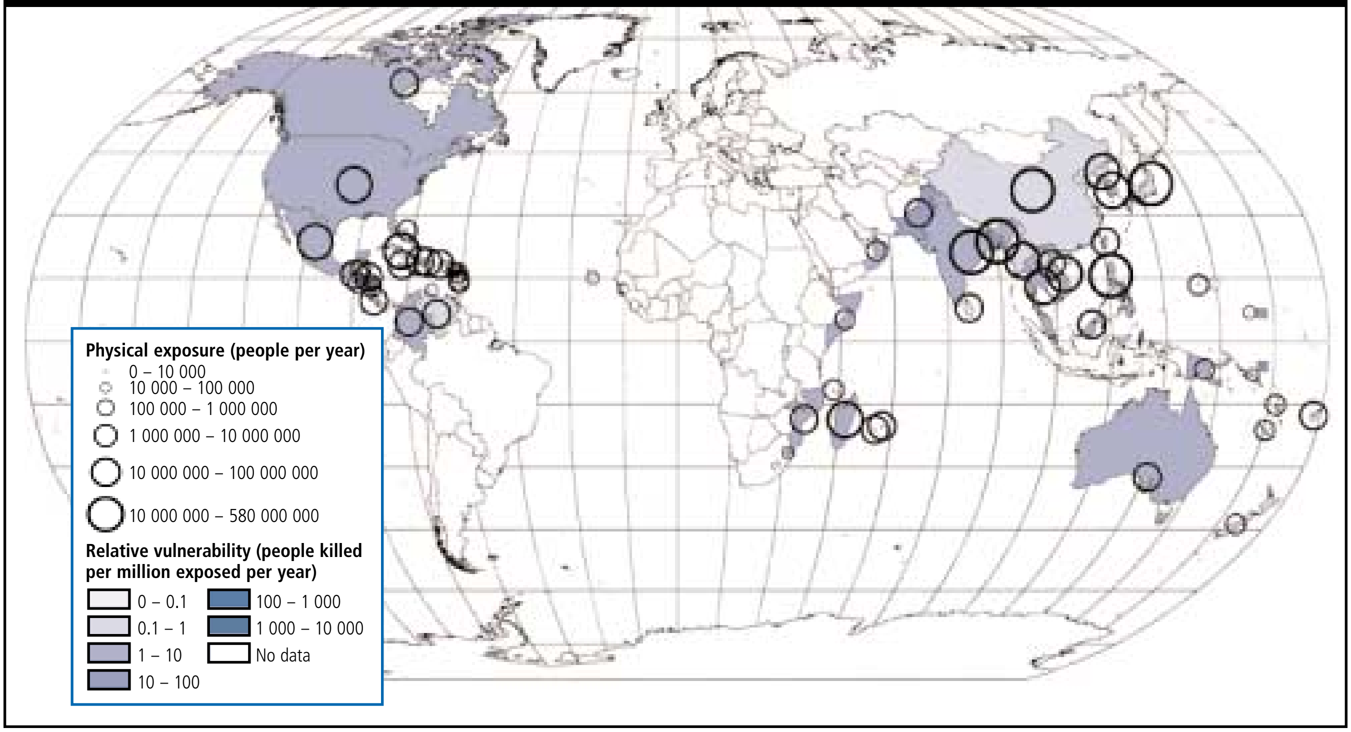


Source: The EM-DAT OFDA/CRED International Disaster Database and UNEP/GRID-Geneva

FIGURE 2.9 RELATIVE VULNERABILITY FOR TROPICAL CYCLONES IN SMALL ISLANDS, 1980–2000

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

FIGURE 2.10 PHYSICAL EXPOSURE AND RELATIVE VULNERABILITY TO TROPICAL CYCLONES, 1980–2000



Source: Université Catholique de Louvain: The EM-DAT The OFDA/CRED International Disaster Database (victims); Carbon Dioxyde Information Analysis Centre: A Global Geographic Information System Data Base of Storm Occurence and Other Climatic Phenomena Affecting Coastal Zones (tropical cyclone frequency); CIESIN, IFPRI, WRI: Gridded Population of the World (GPW), Version 2 (population); Compilation and computation by UNEP/GRID-Geneva

of the impact of Hurricane Mitch in Honduras and Nicaragua was not due to hurricane force winds *per se*, but to the large number of floods, flash floods, landslides and debris flows triggered by the hurricane. The severity of these secondary hazard events was magnified by the effects of processes of environmental degradation that occurred over several decades. These were possibly aggravated in turn by the drought and fires associated with an ENSO (El Niño Southern Oscillation) event the previous year. All these hazard events coincided with a highly vulnerable population in both social and economic terms and weaknesses in early warning and disaster preparedness that led to large losses of life.

Figure 2.9 shows differences in relative vulnerability between Small Island Development States. Haiti is shown to have the highest relative vulnerability, perhaps linked to its small economy, degraded environment and weak institutions of governance. Cuba and Mauritius are the least vulnerable, despite both islands having relatively large proportions of their populations exposed to tropical cyclones. In both cases, though from contrasting political and policy orientations, resources have been made available for early warning, disaster preparedness and evacuation. The positive results are evident.

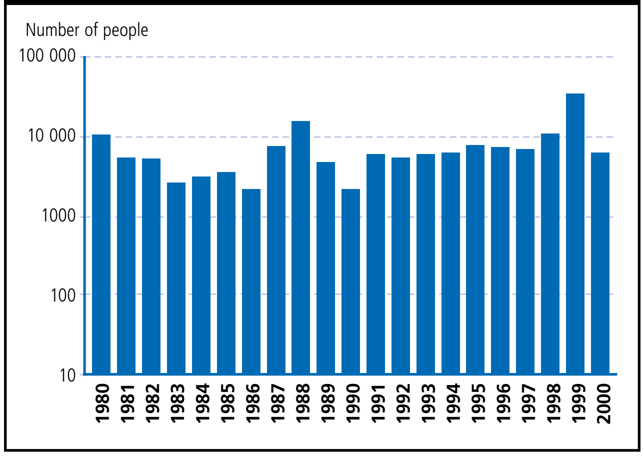
Figure 2.9 also clearly illustrates the influence of human development status on risk. Haiti — the island state most at risk — has low human development, again contrasting with the higher human development countries of Cuba and Mauritius. This does not point to policy implications in itself, but does highlight the close link between development and disaster risk.

The regression analysis carried out for tropical cyclone risk showed a strong correlation between *physical exposure, percentage of arable land* and *Human Development Index* with observed risk. Countries with large, predominantly rural populations and with a low HDI rank will be most closely associated with tropical cyclone risk.

There are a number of reasons why this may be so. Rural housing in many countries will tend to be more vulnerable to high winds, flooding and landslides than urban housing and will generally be associated with higher mortality. Conversely, the weakness or non-existence of emergency and rescue services in rural areas of poor countries and lack of access to disaster preparedness and early warning are all other factors that would help to explain mortality rates. The cyclone preparedness programme in Bangladesh is one of the few success stories in this area. By coupling cyclone shelters and community-based preparedness measures, the programme has managed to dramatically reduce vulnerability from the 1970s to the (still high) levels observed in the 1980-2000 reporting period. The relationship between rural livelihoods, vulnerability and disaster risk is a key issue for further discussion in Chapter 3.

Figure 2.10 (see previous page) shows a World Map of physical exposure and relative vulnerability for tropical cyclones.

FIGURE 2.11 PEOPLE KILLED BY FLOODS, 1980-2000



Source: The EM-DAT OFDA/CRED International Disaster Database

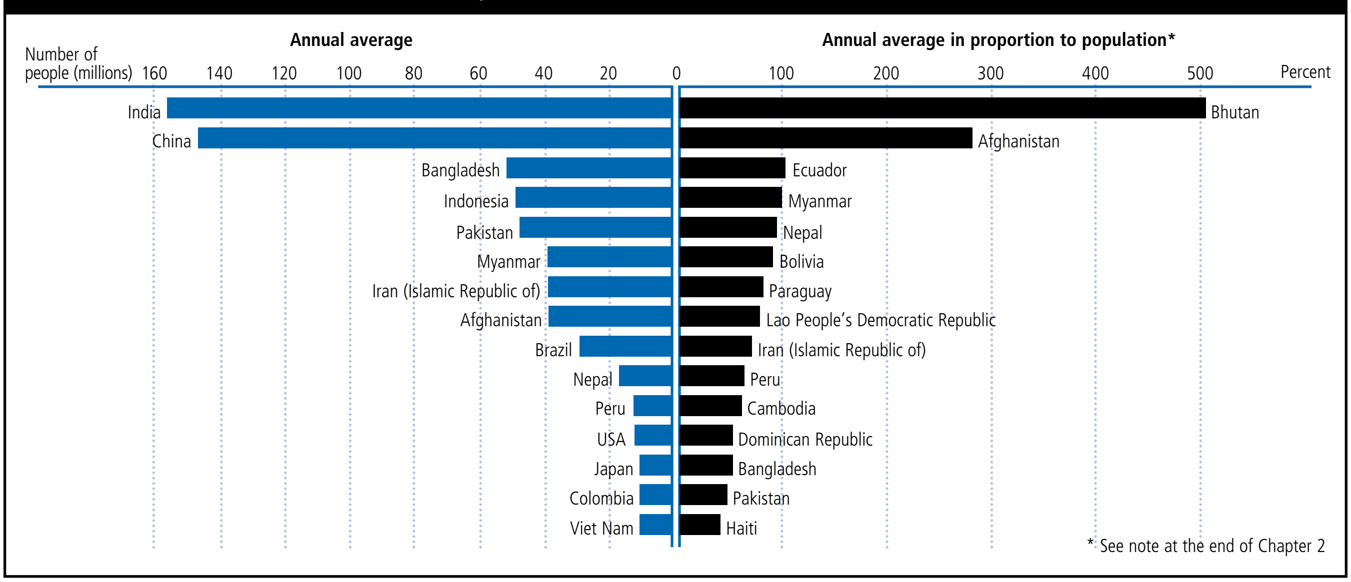
2.2.3 Flood hazard

About 196 million people in more than 90 countries were found to be exposed on average every year to catastrophic flooding. Some 170,010 deaths were associated with floods worldwide between 1980-2000 (see Figure 2.11).

The analysis of physical exposure to floods was weakened by the fact that no single global database was available. In addition, lack of information on duration and intensity of floods impeded the identification of different classes of flood hazard. In the absence of a worldwide floods database, floods registered on the EM-DAT database were used and mapped onto those watersheds where the flood occurred. The entire watershed was mapped as a flood prone area, despite the fact that only a small area of the watershed was usually flooded. This means the number of people identified as being exposed to flooding in the DRI (Figure 2.12) is likely to be greater than numbers observed on the ground. As a consequence, losses calculated as a proportion of exposed populations (Figure 2.13) may appear smaller and the relative vulnerability lower than observed.

The geospatial analysis carried out for the calculation of human exposure identified 147 countries with populations exposed to floods. Figure 2.12 shows those states with the largest exposed populations. Populous South Asian countries (India, Bangladesh, Pakistan) and China figure strongly at the top of the list, as absolute population and population exposed as

FIGURE 2.12 PHYSICAL EXPOSURE TO FLOODS, 1980–2000



Source: UNDP/BCPR; UNEP/GRID-Geneva

a proportion of national populations. This is tied to the large populations living in extensive river floodplains and low lying coasts in this world region. Less populous states with mountainous topography (Bhutan, Ecuador, Nepal), and Central American and Andean states are also flagged among those states as having large absolute and proportional populations exposed to flooding. While these countries are more mountainous than those in South Asia, they nevertheless contain many population centres located in river floodplains.

Comparing the size of exposed populations with the number of recorded deaths to flood events is used as a measure of relative vulnerability in Figure 2.13. Those states closest to the top left-hand corner of the graph show highest relative vulnerability.

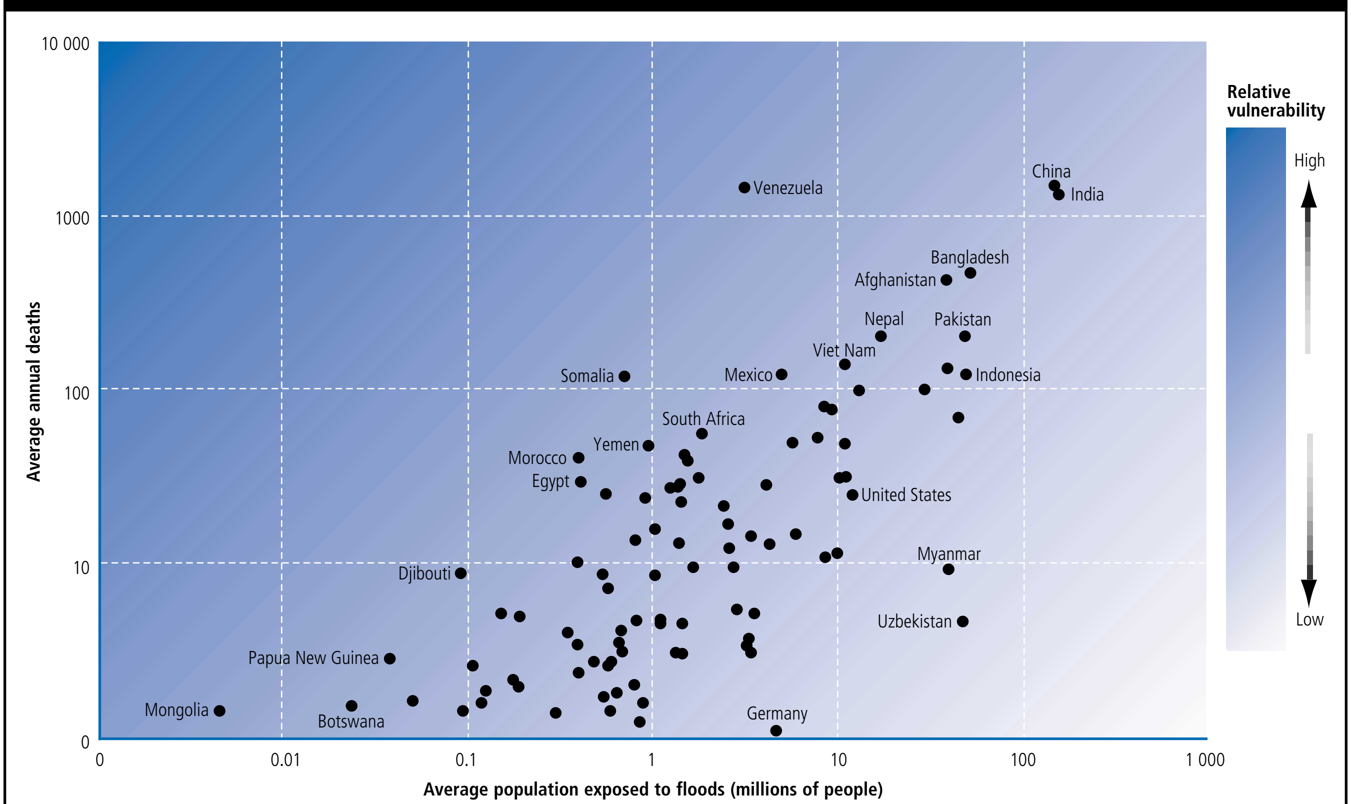
As in the case of earthquake and tropical cyclone hazard, the calculation of human vulnerability to floods clearly illustrates some of the limitations to the DRI model that were outlined in 2.1.2.

Venezuela appears to be the country with highest relative human vulnerability to flooding, based on recorded lives lost to flood events. Again this is due to a single exceptional event occurring in 1999. At the same time, while the event was described generically as a flood in the EM-DAT database, a large proportion of the deaths were associated with debris flows in dense urban communities not located in floodplains.

At the same time, given the fact that whole watersheds were considered when calculating the population exposed, the ratio of killed-to-exposed people (relative vulnerability) does not have the same analytical power that it has for the other hazards, although this does not affect the DRI itself. Floods are made to appear less deadly than in reality. This may explain the positioning of Myanmar and Uzbekistan as countries with apparently low relative vulnerability. Care should be taken in drawing conclusions from this analysis, as it may be that exposed populations are exaggerated or deaths have not been picked up in the recording process.

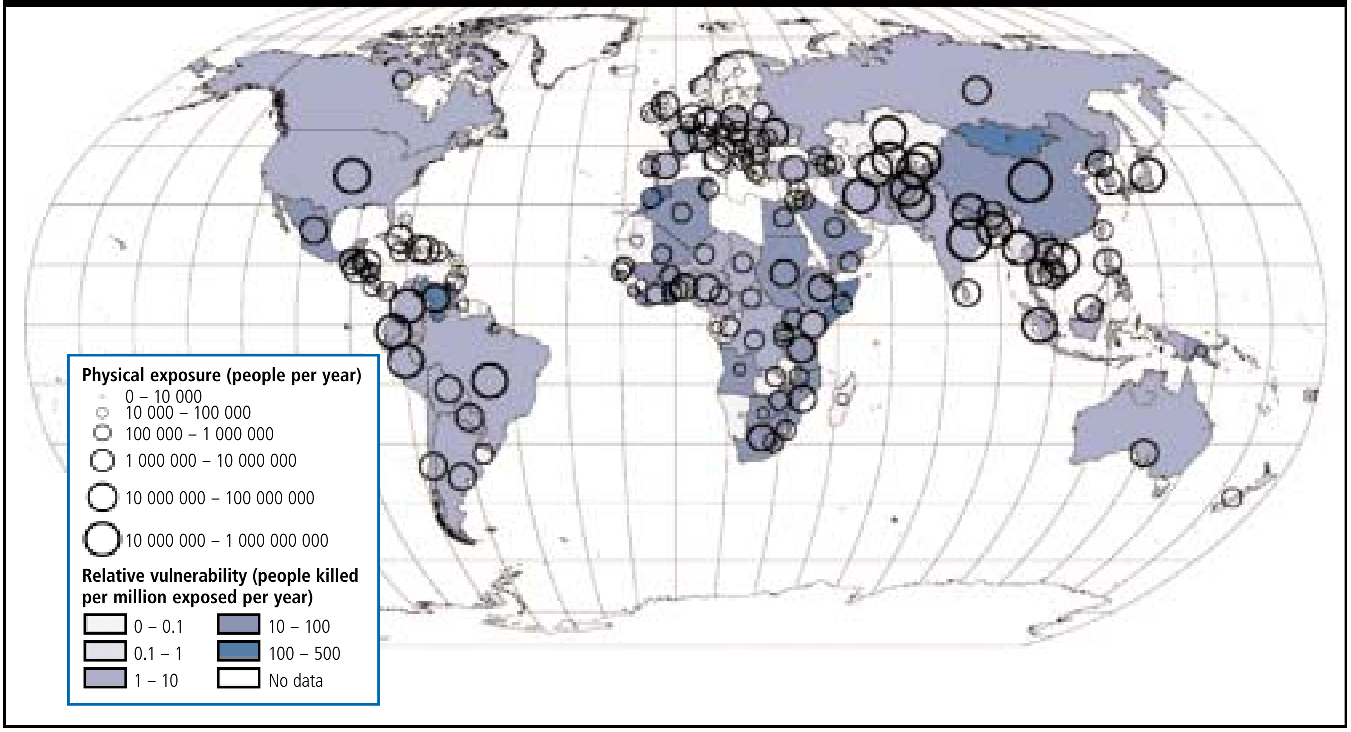
Many flood events are highly localised in character and result in losses that are either below the threshold required to be registered in EM-DAT database or are simply not recorded internationally.

FIGURE 2.13 RELATIVE VULNERABILITY FOR FLOODS, 1980–2000



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

FIGURE 2.14 PHYSICAL EXPOSURE AND RELATIVE VULNERABILITY TO FLOODS, 1980–2000



Source: Université Catholique de Louvain: The EM-DAT The OFDA/CRED International Disaster Database (victims); U. S. Geological Survey: HYDRO1k Elevation Derivative Database (flood affected watersheds); CIESIN, IFPRI, WRI: Gridded Population of the World (GPW), Version 2 (population); Compilation and computation by UNEP/GRID-Geneva

The use of mortality as an indicator of vulnerability to floods could be supported by case specific information on losses to agricultural production, to housing and to social and economic infrastructure, which might be incurred without necessarily causing a large loss of life.

Taking into account and clarifying these different limitations, Figure 2.13 does show a range of countries, particularly in Africa and Asia, with higher human vulnerability to floods than countries such as Germany and the United States of America.

As in the cases of earthquakes and cyclones, there was a strong association with *physical exposure*. With floods this variable was tied to GDP *per capita*, which was inversely correlated with recorded deaths. There was a negative correlation between deaths from flooding and *local density of population*

Countries with low GDP per capita, low densities of population and high numbers of exposed people were most at risk from flood.

These indicators identify pathways into vulnerability to floods. The next stage of assessment would be to explore the detailed relationships that allow this to take place. This is partly the aim of Chapter 3.

Intuitively, one could expect mortality from floods to be high in countries with sparsely populated, poor rural areas, where disaster preparedness and early warning is non-existent and where health coverage is weak and not easily accessible. In such areas people would have less possibility to evacuate from flood prone areas and would be more vulnerable to death through flood related diseases.

Figure 2.14 presents a map of physical exposure and relative vulnerability to floods.

2.3 Unpacking Global Risks

In the first section of this chapter, the DRI was used to demonstrate the ways in which development constructs differential and heterogeneous risk patterns between countries at the global level. At a national level of observation and a local level of resolution, risk and vulnerability exhibit similar patterns of variance and heterogeneity, meaning that different regions and localities within a country are more risk-prone than others.

As was emphasised in Chapter 1 and will be explored in more detail in Chapter 3, risk is configured historically