A traditional wooden suspension bridge made of bamboo or similar natural materials spans across a river. The bridge is supported by numerous vertical posts and ropes. In the background, a small village with thatched-roof houses is visible on a hillside. The scene is captured in a slightly faded, artistic style.

Chapter

3

**Human Vulnerability
to Environmental
Change**

Rosita Pedro was born in a tree, high above the raging, muddy waters of the Limpopo River in full flood. Rosita was born vulnerable, how much more precarious a start to life could anybody have? The reason for Rosita's plight, and that of her mother Sofia, was a mixture of natural phenomena and human impacts. The floods that devastated Mozambique in March 2000 were a natural occurrence but their severity was exacerbated by poor land management, serious erosion of wetlands and overgrazing of grasslands in the upper watersheds of the Limpopo river in Botswana, South Africa and Zimbabwe. Wetlands absorb excess water like a sponge and release it slowly into a watershed or river system, so their shrinking removes that safety valve. Grasslands damaged by overgrazing and burning had become compacted and hardened, allowing water to flow off into rivers instead of seeping into the soil. In addition, meteorologists attributed the torrential rains to exceptionally warm surface temperatures in the Indian Ocean and Mozambique Channel, possibly associated with global warming. In the resulting disaster, several hundred people were killed and thousands displaced and impoverished (Guardian 2000, Stoddard 2000).

Understanding vulnerability

Vulnerability represents the interface between exposure to the physical threats to human well-being and the capacity of people and communities to cope with those threats. Threats may arise from a combination of social and physical processes. Human vulnerability thus integrates many environmental concerns. Since everyone is vulnerable to environmental threats, in some way, the issue cuts across rich and poor, urban and rural, North and South, and may undermine the entire sustainable development process in developing countries. Reducing vulnerability requires identifying points of intervention in the causal chain between the emergence of a hazard and the human consequences (Clark and others 1998).

Many natural phenomena pose threats, including extreme events such as floods, drought, fire, storms, tsunamis, landslides, volcanic eruptions, earthquakes and insect swarms. Human activities have added to the list, with threats from explosions, chemical and radioactive contamination, and other technological

incidents. The risk lies in the probability of exposure to any of these events, which can occur with varying severity at different geographical scales, suddenly and unexpectedly or gradually and predictably, and to the degree of exposure. With an increasing and more widely distributed global population, however, natural disasters are resulting in increasing damage, loss of life and displacement of populations. In addition, human-induced changes to the environment have reduced its capacity to absorb the impacts of change and to deliver the goods and services to satisfy human needs.

The analysis of environmental impacts in Chapter 2 revealed many examples of where individuals, communities and even countries are vulnerable to threats from their physical environment. Environmental change and social vulnerability to it is nothing new. More than 9 000 years ago, the Sumerians of Mesopotamia started irrigating land to meet increased demand for food from a growing population but their civilization eventually collapsed partly because of the waterlogging and salinization that resulted. The Mayan civilization collapsed around 900 B.C. mainly as a result of soil erosion, loss of agro-ecosystem viability and silting of rivers. The Dust Bowl phenomenon of the American prairies in the 20th century resulted from massive soil erosion, and led to communities being uprooted and widespread poverty. During the three days of London's 'Great Smog' of 1952, some 4 000 people died as a result of a lethal combination of air laden with particulates and SO₂ from the widespread burning of coal and a temperature inversion caused by anticyclonic conditions over the city (Met Office 2002).

Some people live in places of inherent risk to humans — areas, for example, that are too hot, too dry or too prone to natural hazards. Others such as Rosita Pedro are at risk because an existing threat has become more severe or extensive through time. Places or conditions which were once safe have been so altered that they no longer safeguard human health and well-being adequately. Many of the children under the age of five who die every year from diarrhoeal disease contract it from drinking contaminated water (see Chapter 2, 'Freshwater').

Most environments are in a constant state of flux because of natural causes and human modifications for food production, settlements, infrastructure, or to

Vulnerability in a crisis area: Mount Nyiragongo

Mount Nyiragongo in the Democratic Republic of Congo has erupted more than 50 times in the past 150 years. Despite this potential hazard, the fertility of the surrounding area with its rich volcanic soils and its proximity to the lake continues to attract people. The eruption of Nyiragongo on 17 January 2002 affected an area already beset by years of civil conflict, which had severely diminished people's coping strategies. Residents received little warning of the impending eruption. The town of Goma, 18 km from the volcano, was devastated by flows of lava 1-2 metres high that engulfed the town and destroyed 14 nearby villages. At least 147 people were killed and many more injured. Approximately 350 000 people were affected, with some 30 000 people displaced and 12 500 households destroyed.

Sources: USAID 2002 and ETE 2000

produce and trade goods. Most intentional changes are designed to harness the environment for human benefit. Domestication of land for intensive food production is one example; harnessing river resources to provide fresh water, energy and transport is another. Such changes may also unintentionally alter the quality or quantity of environmental resources and be difficult to cope with.

Analysing old and new threats to human security shows that human vulnerability to environmental conditions has social, economic and ecological dimensions. The most conspicuous and widely reported manifestation of this vulnerability is when people are affected suddenly and violently by natural hazards such as the eruption of Mount Nyiragongo resulting in the devastation of the town of Goma in the Democratic Republic of Congo (see box). These events turn into disasters when local communities are not able to cope with their impacts. The environmental factors that contribute to human vulnerability, however, are both varied and variable, and are not limited to disaster events; they span the whole sustainable development spectrum.

Vulnerable groups

Although everyone is vulnerable to environmental impacts of some kind, the ability of people and societies to adapt to and cope with change is very varied. Developing countries, particularly the least developed, have less capacity to adapt to change and are more vulnerable to environmental threats and global change, just as they are more vulnerable to

other stresses. This condition is most extreme among the poorest people (IPCC 2001) and disadvantaged groups such as women and children.

The coping capacity of human society is a combination of all the natural and social characteristics and resources available in a particular location that are used to reduce the impacts of hazards (IATFDR 2001). These include factors such as wealth, technology, education, information, skills, infrastructure, access to resources and management capabilities. Between two and three times as many disaster events were reported in the United States in 1999 as in India or Bangladesh but there were 14 times and 34 times more deaths in India and in Bangladesh, respectively, than in the United States (UNEP 2000). The critical factor behind these statistics lies in the advantages enjoyed by US citizens in terms of levels of coping capacity (see also Chapter 2, 'Disasters'). There is, therefore, no direct correlation between the occurrence of extreme events and their level of human impact.

In many instances, coping capacity that was adequate in the past has not kept pace with environmental change. This can happen when traditional options are reduced or eliminated (the settlement of nomads, the introduction of regulations restricting resource use that was previously free), or when new threats emerge for which no coping mechanism exists, resources are lacking, and technology and skills are not available.

Some groups are more exposed than others to particular environmental risks: urban populations are exposed to high levels of contaminant and particulate pollution in the air, slum dwellers often lack the minimum protective infrastructure, employees may be exposed to particular hazards in the work place, and the uninformed may simply not know about the threats that surround them. A wide range of social and economic factors have direct and indirect bearing on human vulnerability to environmental change, including poverty and inequality, and the availability of natural resources. No standard framework exists for identifying all these factors.

Poverty is generally recognized as one of the most important causes of vulnerability to environmental threats, on the basis that the poor tend to have much lower coping capacities, and thus they bear a disproportionate burden of the impact of disasters, conflict, drought, desertification and pollution. But

Culture and climate change

The culture of the indigenous peoples of the Mackenzie basin in northwest Canada is threatened by climate change. Over the past 35 years, temperatures have increased rapidly by about 1°C a decade, with significant results such as melting permafrost, increasing numbers of landslips and forest fires, and decreasing groundwater levels. More frequent forest fires will reduce traditionally important terrestrial, aquatic and bird species. Because of a decrease in water availability, muskrats have already disappeared from the Peace Athabasca delta. Changes such as these in the ecosystem and resource base jeopardize the sustainability of traditional lifestyles that are dependent on wildlife harvested by hunting, fishing and trapping as a prime source of food, income and traditional clothing.

Sources: Cohen and others 1997

poverty is not the only reason. The very young and the old, women and children are often identified as especially vulnerable groups. Refugees, migrants and other displaced groups lack both the physical resources and social structure necessary to respond to threats although paradoxically they may initially benefit from the high visibility of their plight. The urban poor, on the other hand, usually live in obscurity, and in times of disaster their numbers can swell enormously. The mosaics of vulnerability seem so complex as to cast doubt on attempts to describe patterns and estimate trends at the global or even the regional scale. General or gradual economic decline can affect vulnerable groups disproportionately, creating severe but largely hidden hardships (Downing and Bakker 2000).

The cultural dimension is important. Indigenous communities with unique lifestyles intimately adapted to local climate, vegetation and wildlife may be particularly threatened by environmental change (see box above). Traditionally, many indigenous communities developed highly specific coping mechanisms to deal with their environments and periodic extreme events. Such coping mechanisms included adaptive behaviour such as regular seasonal migration or exceptional relocation in times of flooding or drought, and changes in practices such as planting and gathering specific food crops; for example, fruits and foods that are not usually eaten during times of good harvests may be relied upon in times of crop failure. With the breakdown of social patterns, and reduction of options to continue following indigenous lifestyles, such coping mechanisms are also giving way or disappearing.

Poor and indigenous communities are considered

to be more vulnerable to climate-related events such as storms, floods and droughts because of inadequacies in social support services and systems such as water management infrastructure (IPCC 2001). They are also more affected by pests and diseases — especially vector-borne, respiratory and other infectious diseases (Woodward and others 1998, Braaf 1999). In addition, since many poor inhabit isolated rural environments or the margins of large towns and cities, they are more exposed to social problems associated with economic insecurity, inadequate water supplies and lower health standards.

Vulnerable places

Human exposure to environmental threats is not evenly distributed. Some locations, such as high latitudes (see box below), floodplains, river banks, small islands and coastal areas, may pose more risk than others. Human uses or modifications of the environment such as deforestation, increasing paved areas covered by buildings and roads, and river canalization have created impacts that often affect areas a long way from the source of the environmental change, such as far downstream.

Individual choices have an enormous bearing on where people live and work, with the result that human vulnerability is closely related to population density and distribution. Floodplains, low-lying coastal areas and volcanic areas have always been favoured for settlement because of their soil fertility or the availability of flat land. As populations increase and there is more competition for land and resources, areas of higher potential risk are increasingly being

The hazards of living in high latitudes

People living in high latitudes are particularly vulnerable to malignant melanoma (skin cancer). The prevalence of this condition has increased dramatically in the 20th century and has been attributed to increased ultraviolet (UV) radiation resulting from ozone depletion, caused mainly by industrialized countries. Changes in behaviour, such as increasingly outdoor lifestyles and sunbathing, are contributory factors. In the year 2000, 78.5 per cent of melanoma cases, and 73 per cent of melanoma-related deaths reported worldwide, were in developed countries (Ferlay and others 2001). In the United States, there has been a 1 800 per cent rise in reported cases of malignant melanoma since 1930. One in five Americans develops skin cancer, and one American dies of it every hour (US EPA 1998).

settled, such as mountains, steep slopes and locations near sources of pollution. Such settlers are vulnerable to the associated single or combined hazards such as landslides, flooding, volcanic eruptions and toxic chemicals. Again, the poorest strata of society are often the most vulnerable because they have fewer options in where to live.

For various reasons, even the more affluent often choose to live or work in areas prone to environmental threats or hazards. Those living along the earthquake-prone San Andreas fault in California are a prime example, as are those who settle in hurricane belts, on sand spits, on eroding coastlines or in towns where water supplies are inadequate to meet demand. Clearly, the benefits of the location (employment, job security, leisure facilities) are perceived to outweigh the known risks. Measures to mitigate the risks may be sought in the form of insurance or purchasing a scarce commodity such as water but these options are not always appropriate, available or affordable to all members of the community.

In 2002, more than 1 billion urban dwellers, mostly in Africa, Asia and Latin America, live in slums or as squatters (UNCHS 2001). Of the projected 1 billion new urban dwellers by 2010, most will probably be absorbed by cities in developing countries that already face multiple problems such as shortages of adequate housing, infrastructure, potable water supplies, adequate sanitation and transportation systems as well as environmental pollution. The urban poor, unable to

Floods caused by glacial lake outbursts

Glacial lake outburst floods (GLOFs) are catastrophic discharges of water resulting primarily from melting glaciers.

Global warming over the past half century has led to an accelerated retreat of the glaciers and enlargement of several glacial lakes in the Hindu Kush and Tibetan Himalayas. In Bhutan, for example, some glaciers are retreating at a rate of 20-30 metres a year. Many glacial lakes are dammed by unstable moraines. Occasionally these dams burst and release large amounts of stored water, causing serious flooding downstream and along the river channel. The water contains substantial debris and causes serious damage — often at great distances from the outburst source; in Pakistan, damage has occurred 1 300 km from the outburst source. Such flash floods are a common problem in countries such as Bhutan, China (Tibet), India, Nepal and Pakistan.

In Nepal, records indicate that GLOFs occur once every three to ten years. Over the past few decades at least 12 GLOFs have caused major damage to infrastructure. For example, Dig Tsho glacial lake in Bhutan burst on 4 August 1985, causing significant loss of life and destroying the nearly completed Namche hydropower plant, as well as 14 bridges.

Sources: WECS 1987, Watanabe and Rothacher 1996

afford alternatives, are frequently forced to live in areas with the worst urban services and most unhealthy environmental conditions, exposed to multiple hazards and increased risk, their vulnerability enhanced by overcrowding.

Some communities have become more vulnerable because the scarcity of critical resources such as land, fresh water and forests is contributing to conflicts. These environmental scarcities do not usually cause wars among countries but they can generate severe

Africa's Lake Victoria basin: multiple dimensions of vulnerability

An estimated 30 million people depend on Lake Victoria, a lake whose natural resources are under increasing stress. The population on the shore has grown fast over the past century with corresponding increases in the demand for fish and agricultural products. Following the introduction of gill nets by European settlers at the beginning of the 20th century, populations of indigenous fish species declined. Many were specially adapted to eat algae, decaying plant material, and snails that host the larvae of Schistosomes that cause bilharzia in humans. The lake started to eutrophicate and people became more vulnerable to disease.

As fish catches declined, non-native species were introduced, so causing further stress to indigenous fish. The greatest impact resulted from the introduction of Nile perch (*Lates niloticus*) in

the 1960s, as the basis of commercial freshwater fisheries. This had repercussions on the local fishing economy and distribution of wealth. Local people who previously met most of their protein requirements from the lake began to suffer from malnutrition and protein deficiency. Although 20 000 tonnes of fish are exported annually to European and Asian markets, local people can afford only fish heads and bones from which the flesh has been removed.

Wetlands around the lake have been converted to grow rice, cotton and sugarcane, and their function as natural filters for silt and nutrients has been lost. Run-off now carries soil and excess nutrients from the cultivated areas straight into the lake. The resulting algal growth clouds the surface water and reduces oxygen availability, seriously affecting the habitat of endemic fish species, which

prefer clear waters, while their predator, the Nile perch, thrives in such murky waters. This further aggravates food insecurity in lakeside communities.

Increased nutrients, much in the form of sewage, have stimulated the growth of the water hyacinth (*Eichornia crassipes*), one of the world's most invasive plants. This has seriously affected water transport and paralysed many local fisheries. By the end of 1997, the 70 per cent decline in economic activity reported at Kisumu port was attributable to water hyacinth choking the port and fish landings. The dense cover of water hyacinth also stimulated secondary weed growth, and provided habitats for snails and mosquitoes — this in an area where the incidence of bilharzia and malaria is already among the highest in the world.

Source: Fuggle 2001

social stresses within countries or across borders, helping to stimulate sub-national insurgencies, ethnic clashes and urban unrest. Such civil violence affects developing societies particularly because they are generally more dependent on environmental resources and less able to buffer themselves from the social crisis that environmental scarcities cause (Homer-Dixon 1999).

Environmental change

Two basic functions performed by the environment are the 'source' or production function that supports the livelihood of millions who depend upon environmental resources, and the 'sink' or pollution absorption and cleansing function essential for human health and well-being. Not only are these two functions closely connected in a cycle of production and renewal but they are being increasingly impaired and degraded by human impacts.

Watershed management and flooding

Poor land-use management can have profound effects on people. By 1986, deforestation in the upper reaches of the Yangtze basin in China had reduced forest cover from 22 per cent of total area in 1957 to only 10 per cent. As a result, soil erosion from the upper reaches and siltation in the middle and lower reaches had become intense. In 1998, the most severe flood in Chinese history hit the Yangtze valley, affecting 223 million people and causing more than US\$36 billion in economic losses (Shougong 1999).

In July 1997, vast areas of southern Poland, the eastern Czech Republic and western Slovakia experienced one of the most disastrous floods in history when the Oder, Elbe, Vistula and Morava Rivers overflowed. In Poland alone, flooding affected one-quarter of the land area, including nearly 1 400 towns and villages, destroyed 50 000 homes and caused 162 000 people to be evacuated. Total damage was estimated at US\$4 billion. The severity of the floods was attributed to the destruction of forest and wetlands, engineering works on the main rivers and tributaries, and the removal of water-retaining vegetation which made riverine areas more susceptible to flooding. Floods have become an increasingly regular occurrence for more than a decade (EEA 2001).

Degradation of natural resources such as land, fresh and marine waters, forests and biodiversity threatens the livelihood of many people but especially the poor. For example, water tables are falling fast under the North China plain. In 1997, almost 100 000 wells were abandoned apparently because they ran dry as the water table fell, but 221 900 new wells were drilled. The drilling of so many wells reflects a desperate quest for water (Brown 2001).

The 'sink' function of the environment operates through such processes as nutrient recycling,

decomposition, and the natural purification and filtering of air and water. When these functions are impaired, health can be jeopardized by contaminated household water, sanitation problems, indoor air pollution, urban air pollution and agrochemical pollution.

How people are affected

Environmental change may have impacts on health, habitat and infrastructure, economy, society and culture, increasing vulnerability. The sections below discuss three of these areas: health, food security and economic effects.

Health

Human health is increasingly determined by environmental conditions (Rapport and others 1999, McMichael 2001). According to a report from the World Health Organization (WHO 1997), for example:

- Deteriorating environmental conditions are a major contributory factor to poor health and poor quality of life. Mismanagement of natural resources, excessive waste production and associated environmental conditions that affect health pose major challenges to sustainable development.
- Impoverished populations living in rural and peri-urban areas are at greatest risk from degraded environmental conditions. The cumulative effects of inadequate and hazardous shelter, overcrowding, lack of water supply and sanitation, unsafe food, air and water pollution, and high accident rates, have serious effects on the health of these vulnerable groups.
- Poor environmental quality is directly responsible for some 25 per cent of all preventable ill health, with diarrhoeal diseases and acute respiratory infections heading the list.
- Two-thirds of all preventable ill health due to environmental conditions occurs among children.
- Air pollution is a major contributor to a number of diseases, and to a lowering of the quality of life in general.

There are regional differences in the way human health is vulnerable to environmental degradation. Communities in many parts of Central and South America, Central Africa and Asia are highly vulnerable

to water-borne and vector-borne diseases. Air pollution threatens large urban areas and mega-cities, most of which are in developing countries. People in developed countries are more vulnerable to exposure to toxic chemicals and technological accidents but there are notable exceptions such as arsenic contamination in south Asia (see box).

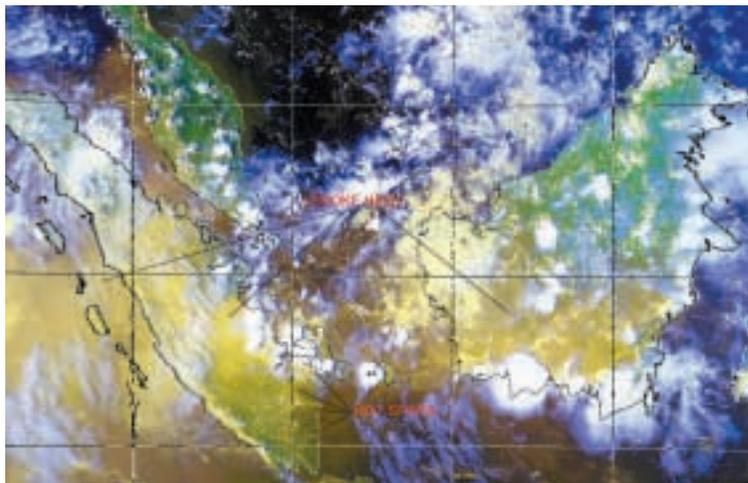
Overall, it is estimated that 25-33 per cent of the global burden of disease is attributable to environmental factors (Smith, Corvalán and Kjellström 1999). Recent estimates suggest that environment-related premature death and illness account for 18 per cent of the total burden of disease in the developing world (Murray and Lopez 1996). This comprises contributions from water supply and sanitation (7 per cent), indoor air pollution (4 per cent), vector-borne diseases (3 per cent), urban air pollution (2 per cent) and agro-industrial waste (1 per cent). In sub-Saharan Africa the figure is even higher at 26.5 per cent, mainly related to water supply and sanitation (10 per cent) and vector-borne diseases (9 per cent).

Globally, 7 per cent of all deaths and diseases are due to inadequate water, sanitation and hygiene (UNDP, UNEP, World Bank and WRI 1998). Approximately 5 per cent are attributable to air pollution (Holdren and Smith 2000). Every year, environmental hazards kill 3 million children under the age of five (WHO 2002). Current estimates suggest that 40-60 per cent of those deaths are due to acute respiratory infection resulting from environmental factors, particularly particle emissions from solid fuel use (Smith, Corvalán and Kjellström 1999). In the United States, a $10 \mu\text{g}/\text{m}^3$ increase in fine particle air

Arsenic contamination in Bangladesh

In Bangladesh, naturally occurring arsenic in underground sediment leaches into the groundwater. More than 25 per cent of the 4 million tube wells that are the main source of drinking water contain dangerous levels of arsenic. Nearly 75 million people are vulnerable to arsenic poisoning which can cause skin cancer, kidney and liver failure, respiratory problems and death. About 24 million people have already been exposed to arsenic poisoning. Agricultural production is affected by arsenic-contaminated water in a 500-km swath of rice paddies and banana groves between the Ganges River and the Indian border.

Sources: Karim 2000, BICN 2001a and 2001b, and UN Wire 2001



pollution results in a 4 per cent increase in general morbidity, a 6 per cent increase in cardio-pulmonary mortality and an 8 per cent increase in lung cancer mortality (Arden-Pope and others 2002).

In the short term, disease due to environmental change is likely to have more impact on developing countries than on developed ones. This is partly because developed countries have devoted considerable effort to reducing the health threat from dirty water, poor sanitation and using solid fuels in open fires inside homes. The same is not true for most developing countries. As a result, exposures to particulates for non-smokers are often an order of magnitude lower in developed countries than in developing ones. In Helsinki, for example, the particulates in the air come mainly from indoor dust, cleaning products, traffic and long-range transport (Koistinen and others 2002). In developing countries, the use of solid fuel as a primary energy supply dominates the exposure of non-smokers to particle pollution, especially among women and children in rural and slum environments. In the past decade, smoke haze from forest fires has also become an important source of respiratory disease (see image above). Furthermore, most developing countries still lack the resources to deal effectively with public health crises and are situated in regions where many water-borne and vector-borne diseases are acute.

Microbiological contamination of the sea by sewage pollution has precipitated a health crisis of massive proportions globally. Bathing in polluted seas is estimated to cause some 250 million cases of gastroenteritis and upper respiratory disease every year, with an estimated annual cost worldwide of about

Satellite image shows extensive smoke haze over Indonesia and neighbouring areas on 20 October 1997. Hot spots are probable areas of forest fires. Smoke haze had severe effects on the health of people over a wide area of Southeast Asia

Source:
Meteorological
Service of Singapore
2002

US\$1.6 billion. Some of these people will be disabled over the longer-term, suggesting that the global impacts of marine pollution are comparable to those of diphtheria and leprosy (see also page 181). Eating sewage-contaminated shellfish causes an estimated 2.5 million cases of infectious hepatitis a year, of whom some 25 000 die and another 25 000 suffer long-term disability resulting from liver damage. The annual global burden on human health is estimated to equal some 3.2 million DALYs — comparable to the worldwide impact of all upper respiratory infections and intestinal worm diseases — and to cost world society some US\$10 billion annually (GESAMP 2001).

Food security

There is only a fine line between harnessing environmental resources to provide goods and services to meet people's needs, and misusing, damaging or overexploiting those resources to the point where people's lives, health or well-being are put at risk and they become vulnerable.

Food security means being able to obtain a nutritionally adequate, culturally acceptable diet at all times through local non-emergency sources. This requires both adequate food production or imports, and economic access to food at the household level, at all times, to ensure a healthy active life (Vyas 2000). This idea goes well beyond the traditional concept of hunger: it embraces a systematic view of the causes of hunger and poor nutrition within a community

Food security: is the green revolution losing momentum?

From independence until the mid-1970s, India faced problems of food scarcity. The green revolution that began in the mid-1960s combined new seed and fertilizer technology, substantial increases in irrigated land, infrastructure development and rural extension to all regions. The result was an unprecedented increase in the yield of major cereals such as wheat and rice, decreased production costs and a consequent fall in prices that enabled poor people to buy wheat and rice. The production of foodgrains increased from 50.8 million tonnes in 1950-51 to 199.3 million tonnes in 1996-97. By the mid-1970s, India was self-sufficient in food grains.

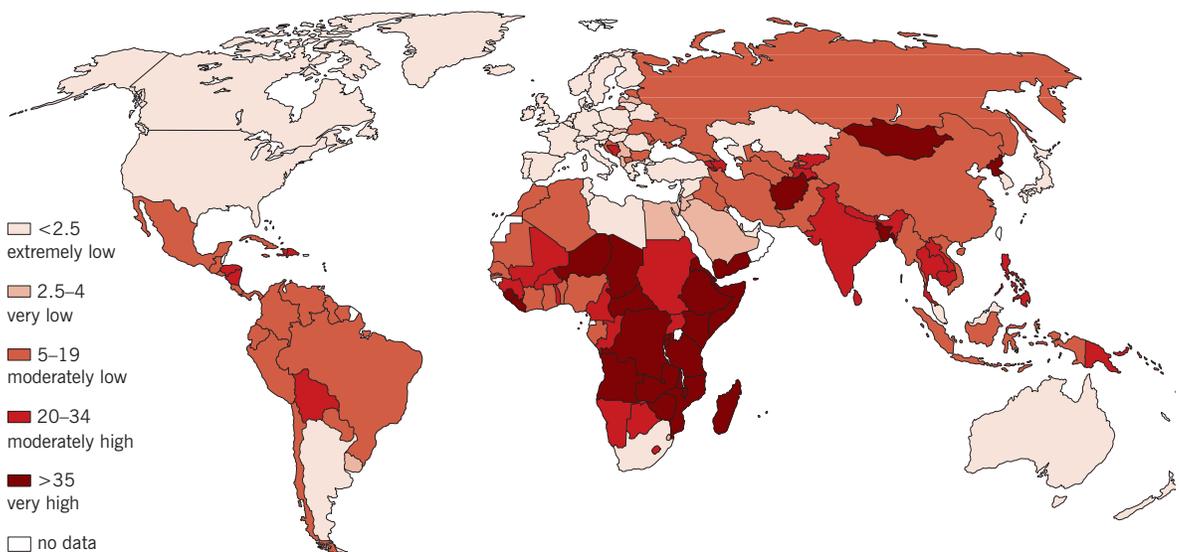
Despite the impressive results of the 1980s, recent trends in aggregate production growth have been a matter for serious concern. Foodgrain production grew by 3.43 per cent on average during the period 1991-92 to 1996-97 but the foodgrain production target of 210 million tonnes was not met. In 1996-97, the production of rice stood at 81.3 million tonnes, about 9 per cent less than the targeted 88 million. These figures must be viewed against a significant jump in the use of fertilizer and pesticides. The consumption of fertilizers (NPK) that had been stagnant at around 12 million tonnes between 1990-91 and 1993-94, increased to reach the level of 14.3 million tonnes in 1996-97.

Source : Planning Commission of India 2001

(Umrani and Shah 1999), recognizing both physical and economic vulnerability.

Projections of production increases suggest that the global availability of food should be adequate in

Undernourishment by country (% of population undernourished)



coming decades. Aggregate statistics, however, are often misleading, and can hide the real situation on the ground. For example, per capita food production in Africa has declined slightly over the past 30 years and decreased significantly in the former Soviet Union since 1990 (UNDP, UNEP, World Bank and WRI 1998).

Agricultural growth as a consequence of the Green Revolution has also had an adverse impact on the environment in terms of nutrient mining, increase in soil salinity, waterlogging, depletion of underground water and the release of nitrogen into watercourses (see box on page 308).

Economic losses

Human vulnerability to environmental change has an important economic dimension. Human well-being is inextricably linked to ecosystems through the goods and services that ecosystems provide. This includes both marketed goods and services, such as food or forest products, and non-marketed ones such as water flow regulation, so that any reduction or degradation in supply leads to a loss of human welfare (see box below). In Japan, for example, the damage to agricultural crops caused by tropospheric ozone amounts to an estimated US\$166.5 million yearly in the Kanto region alone (ECES 2001).

The economic dimensions of vulnerability to environmental change often focus on the impact of natural disasters or other extreme events. While total losses may be highest in developed countries, with their expensive infrastructure, the impact on the economies of developing regions may be greater. For example, the 1991-92 drought that hit most of Southern Africa resulted in a decline of 62 per cent in the Zimbabwe Stock Market (Benson and Clay 1994).

The cost of resource degradation in India

Economic development has been the watchword in India's march into the 21st century, but a conservative estimate of environmental damage put the figure at more than US\$10 billion a year, or 4.5 per cent of GDP, in 1992. A breakdown of the estimated costs shows that urban air pollution costs India US\$1.3 billion a year; and water degradation has associated health costs of US\$5.7 billion a year, nearly three-fifths of total environmental costs. Land degradation causes productivity losses of around US\$2.4 billion and deforestation leads to annual losses of US\$214 million.

Source: Suchak 2002

'It is not so much that humanity is trying to sustain the natural world, but rather that humanity is trying to sustain itself. The precariousness of nature is our peril, our fragility.' — *Amartya Sen, Nobel Laureate Economist*

The potential economic losses of non-marketed ecosystem goods and services and the impact on human vulnerability are likely to be even higher than for marketed goods and services. Equally, little attention is paid to the high economic cost of more gradual environmental degradation and loss of natural resource potential.

Responding to human vulnerability

The cumulative evidence for increasing human vulnerability to environmental change calls for a significant policy response and action on several fronts. Social responses have frequently focused on 'downstream' measures, designed to mitigate the hardships and cushion the impacts of environmental change or natural disaster after the event, rather than on interventions intended to modify basic driving forces ahead of a potential crisis. The onset of conditions that give rise to threats and vulnerability can often be gradual or inconspicuous. Donors are often ready to offer relief once a high-profile disaster such as a famine or flood has occurred but they are less likely to finance precautionary measures. 'Upstream' intervention is generally highly cost-effective and should be given greater priority.

Levels and trends of vulnerability for different groups need to be assessed regularly as a basis for designing specific measures for vulnerability reduction and evaluating their impact. Governments need to assess and map national threats due to environmental change, particularly those that may be growing, and to institute early warning, mitigation and response measures to reduce the human and economic costs of disasters that are in part avoidable. Vulnerability should be recognized as a key indicator of the seriousness of environmental problems such as global warming (Adger and others 2001). It should be a focus for developing policies that seek to help people avoid, cope with or adapt to adverse effects of environmental change. Prior action to mitigate threats and to boost people's capacity to cope with or prepare for change makes more sense than remedial efforts after the

event. The following sections discuss some possible approaches.

Reducing vulnerability

There is a large and widening vulnerability gap between well-off people, with better all-round coping capacity, who are becoming gradually less vulnerable, and the poor who grow increasingly so. It is vital to the sustainable development effort that this gap is addressed, as well as vulnerability itself. For the most significant improvements, priority should go to policies that reduce the vulnerability of the poor as part of general strategies for poverty reduction. This is in keeping with the general priority being given to poverty reduction as essential to sustainable development.

Increasing human vulnerability is only now achieving wide recognition, so that few existing policies specifically address this issue. However, a number of studies, programmes and projects are currently addressing aspects of human vulnerability and these have already yielded valuable lessons for future policy action. Two types of policy response are possible: reducing the threat through prevention and preparedness initiatives, and improving the coping capacity of vulnerable groups to enable them to deal with the threat.

Reducing exposure to threats

Exposure to threats can be minimized by reducing the risk — in other words the probability that damage will

occur. In theory, exposure can always be avoided by moving people out of hazardous situations but this is not always feasible in practice. Currently, the prediction of threats is an imperfect science. People will not evacuate their homes and businesses unless absolutely necessary, and a few false alarms will quickly discourage any further response.

Human exposure can be reduced by reinforcing infrastructure — for example, by upgrading building codes, improving flood control, planting trees for soil stabilization or avalanche control, and providing safe havens or shelters. Many of these measures require significant long-term investments.

Better environmental management, improved policies to protect ecosystems and environmental restoration can be effective and practical ways to reduce vulnerability. In the long term, every effort to achieve sustainability in natural resource use, to reduce waste generation and pollution, and to bring society back into balance with the local environment and global systems should reduce human vulnerability. One of the main goals of integrated environmental planning should be the integration of vulnerability assessment and reduction.

Many natural systems evolved in response to specific major environmental threats and have a built-in capacity to absorb them. Vegetation stabilizes stream banks, slows run-off and prevents erosion. Beaches absorb wave energy and protect coastlines. Environmental threats may well increase with the destruction of such natural defences. Their restoration is the best response to the problem because it is usually less expensive and more permanent than artificial defensive construction which sometimes simply moves the threat elsewhere. Many flood control works have aggravated problems elsewhere on river systems and are now being systematically reversed.

Reinforcing coping capacity

Improving the coping capacity of groups at greatest risk can do much to reduce the damage caused by extreme events or environmental degradation. The ability to cope with threats includes the ability to absorb impacts by guarding against or adapting to them. It also includes provisions made in advance to pay for potential damage, for instance by mobilizing insurance repayments, savings or contingency reserves.

Attempts to conserve water upstream may simply shift the problem downstream — restoration of natural defences is often the best way to decrease overall vulnerability

Source: UNEP, John L. Perret, Topham Picturepoint



People can draw on both tangible and hidden assets for coping with change, assets that can help to reduce the probability and magnitude of harm (Chambers 1997). They can be helped to identify and mobilize whatever assets they have in time of need and these may be decisive factors in damage prevention. They include economic assets, social and political assets, ecological assets, infrastructure assets and personal assets. Strategies that take account of the existing assets of vulnerable groups and their likely needs may also cushion the damaging impacts of unavoidable events or catastrophes. Restitution of lost or damaged assets through rapid response to sudden or extreme events in the form of rescue, relief and rehabilitation (for instance, provision of clean water, health care, shelter and food) may be all that is required to reduce hardship to manageable levels.

Institutional arrangements — including the preparedness of public, private and social services — are an important aspect of coping (Adger and others 2001). Institutional preparedness can be a decisive factor in reducing vulnerability. For example, the flooding of the River Oder in 1997 caused less damage on the German side than it did in Poland (GACGC 2000) because the Germans were better prepared. People in vulnerable areas should make institutional arrangements to respond to potential crises. This requires foresight but often can be done at little or no cost. The UNEP Awareness and Preparedness for Emergencies at Local Level programme (APELL) is a good example of institutional preparation to cope with potential environmental threats (UNEP 2002).

Adapting to threat

Where a threat cannot be reduced or eliminated, adapting to it can be an effective response. Adaptation refers both to physical adjustments or technical measures (such as constructing a higher sea wall) and changing behaviour, economic activities and social organization to be more compatible with existing or emerging conditions or threats. The latter requires adaptive capacity, including the ability to develop new options and to deliver them to vulnerable populations.

Some environmental changes, such as expected climate change from global warming, have such long lead times that some degree of environmental change is inevitable even if measures to control the situation are implemented rapidly. Some adaptation measures may then be essential. Efforts to predict the probable

Breakdown of traditional coping mechanisms: Kenyan pastoralists

Pastoralists' coping strategies for drought include migration to available water and pastures, setting aside dry grazing pastures and splitting herds to minimize risks. In the past, there were fewer pastoralists and they had large herds to survive droughts. During extreme droughts, animals would graze unused swamps, forests and areas remote from water. These ancient drought responses, however, are often no longer available to pastoralists, either because land has been sold or because of barriers erected by farmers, ranchers, industry and city residents. Other traditional drought responses, such as raiding neighbouring cattle and killing wildlife for meat, may be both illegal and no longer appropriate.

In 2000, Kenya experienced its worst drought for 40 years. Its effects were severe because of the:

- breakdown of traditional coping methods;
- increasing population pressure due to development of land formerly used as dry season grazing;
- land tenure system which restricts access to essential resources;
- extension of the drought to areas usually not affected;
- poor security, especially in arid and semi-arid land areas, that restricts animal and human movement;
- inadequate preparedness due to lack of access to or ignoring of weather forecasts;
- scepticism about traditional early warning systems and weather forecasts; and
- lack of an effective marketing infrastructure for livestock.

Source: UNEP and Government of Kenya 2000

impacts of climate change should help to determine the adaptive actions that are necessary and the speed with which they should be implemented.

Various investments in adaptive capacity have been made following advances in early warning. Several countries have tried to change patterns of agricultural practice so that crops more suited to periodic changes in growing conditions can be grown in years affected by climate fluctuations associated with El Niño and La Niña events (see box above). The risk of crop failure is thus reduced.

Early warning

One of the most effective responses to human vulnerability to environmental change is to strengthen mechanisms for early warning. Many actions can be taken to protect life and property if warning is received in time. While some threats are inherently unpredictable, many of those arising from threats from environmental degradation and mismanagement, and from human activities, can now be anticipated with some precision. Early warning capacities are increasing steadily with technological advances in environmental observing, assessment and

Advantages of foresight: predicting El Niño

Forecasting El Niño events can help countries with their strategic planning to ensure security in areas such as agriculture, fishing, water resource management, flood control and energy supply, thereby reducing the vulnerability of the people and country. The Tropical Atmospheric-Ocean (TAO) array of ocean observation buoys, using measurements of surface sea temperature, helps provide the first indication of an El Niño six to nine months ahead of the event. A number of institutions in Peru, including the Instituto Geofísico, are working together to improve predictions of El Niño events using statistical modelling. Such forecasts of rainfall and hot and cold events have helped farmers to plan better use of water resources for irrigation, and fishermen to prepare better for variations in fish stocks. Forecasts of the next rainy season are issued in Peru each November, after which farmers' representatives and government officials meet to decide the appropriate combination of crops to plant. A forecast of El Niño weather will mean recommendations to plant crops that prefer wet conditions, such as rice, and to avoid crops that prefer drier weather. Australia, Brazil, Ethiopia and India are some of the countries that have taken similar initiatives.

Source: NOAA/PMEL/TAO 1998, IOC 1998, CNA Peru 2001

communications. Examples are the cyclone early warning systems that have been established in India and Mauritius.

Conventionally, early warning means an urgent indication of an impending hazard (ISDR Secretariat 2001). There is a need for both sudden onset warnings, for imminent disaster threats such as tropical storms and floods, and slow onset warnings for disseminating information about disasters that may

develop over time such as famine and drought.

The term early warning is often taken to mean 'prediction' when in fact the occurrence of many threatening events is essentially unpredictable. Early warning simply means that an event is imminent and the time to escape from it or take action against it is now. Early warning information can be produced in the context of a broader vulnerability assessment process, which includes the production and communication of forecast information and the incorporation of that information in user decisions.

To be effective, an early warning system must be able to stimulate a timely response before an event takes place. It must identify who are the users of early warning information and what is the most efficient way to reach them with credible information to enhance their powers of decision-making. It must then translate relevant data into early warning indicators that decision-makers can easily interpret and use.

Ultimately, the single most important factor that will lead governments to incorporate the use of early warning systems and information in decision-making is the political will to invest in response systems, both nationally and internationally (Buchanan-Smith 2001). One example of an operational early warning system which has generated such a response is the Famine Early Warning System Network for Africa (see box).

Famine Early Warning System Network (FEWS NET)

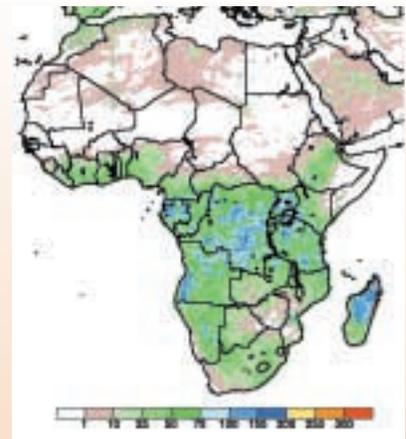
FEWS NET is a USAID-funded partnership to improve food security in 17 drought-prone countries in Africa, through African-led food security and response planning networks that reduce the vulnerability of people at risk. FEWS NET, scheduled to run until 2005, is the successor to FEWS, which began in 1985. The goal is to strengthen the abilities of African countries and regional organizations to manage threats to food security by providing early warning and vulnerability information. Achievements include:

- close collaboration with regional organizations and governments in preparing contingency and response plans for El Niño in 1997;
- co-sponsoring regional seasonal rainfall forecasts for user-friendly dissemination;
- advances in satellite imagery interpretation through FEWS NET partners;
- forecasting the quality of harvests in the Sahel;
- strengthening capacity by seconding FEWS

NET/USGS meteorologists to specialized centres in Nairobi (Kenya), Harare (Zimbabwe) and Niamey (Niger);

- early warning of an impending food crisis in Ethiopia in 2000;
- participating closely in national systems and regional institutions to develop common methodologies to assess vulnerability;
- emphasizing livelihood protection by mixing short- and long-term programme and policy interventions;
- exploring linkages between environmental stress, food insecurity and conflict; and
- working with governments and their partners to shorten the time between early warning and response.

Source: FEWS 2002



Ten-day rainfall forecast of the type provided by FEWS. This one was for 1–10 March 2002

Source: NOAA 2002

Assessing and measuring vulnerability

Vulnerability assessment measures the seriousness of potential threats on the basis of known hazards and the level of vulnerability of societies and individuals. It can be used to translate early warning information into preventive action (IDNDR 1999) and is a necessary element in early warning and emergency preparedness. Ideally, the results should be incorporated directly into the long-term planning of institutions and governments, and should foster institutional responsiveness to increasing vulnerability, and action for disaster preparedness and mitigation. Vulnerability assessments are widely applied and used in the fields of climate change and natural disaster management, where they provide the basis for effective warning systems.

Assessments of vulnerability can be made for both people and the environmental systems that provide goods and services. They should identify the location of vulnerable populations, the threats to their well-being and the extent of their vulnerability; the risks to the environmental capacity to provide goods and services; and the preventive steps that can be taken to improve environmental conditions and reduce the negative impacts of human action on the environment. This information is then assembled into a knowledge base that is accessible, scientifically reliable and easy

to use, which can help policy-makers and planners seeking to formulate adequate responses (see box below).

Calculation of coping capacity would be a valuable tool for understanding how and why burdens of environmental degradation are unevenly distributed around the globe, and why the potential impact of different threats may be more or less catastrophic depending upon a group’s ability to cope. In the case of diseases such as cholera, governments of high-income countries would be likely to respond to the risk of an outbreak with costly prevention and early warning programmes such as a cholera-monitoring network. Yet this response would not be affordable in many other parts of the world.

When calculating vulnerability, geographical scale is important. A single national figure may hide many significant variations. Although an assessment for high-income countries would show low overall vulnerability, there may be sub-populations that are highly vulnerable. For instance, one country may be less vulnerable to outbreaks of vector-borne disease triggered by climate change than another, because of the medical system’s capacity to respond, but those without medical insurance may still be particularly vulnerable. Furthermore, societies that are well equipped to cope with present vulnerability may lack

Environmental vulnerability of small island developing states

The South Pacific Applied Geosciences Commission (SOPAC) is developing an index of the vulnerability of the environment to both human and natural hazards. SOPAC identifies three aspects of environmental vulnerability: level of risks (or pressures) on the environment; resilience of the environment to pressures, or intrinsic vulnerability; and the level of degradation of ecosystems, or extrinsic resilience. A total of 47 indicators are used: 26 indicators of risk, 7 indicators of resilience and 14 indicators of environmental degradation. The indicators are also classified by category; meteorological, geological, biological,

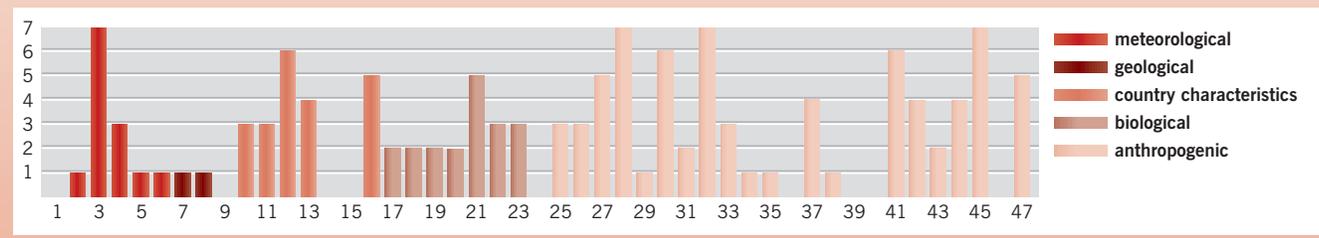
anthropogenic and intrinsic country characteristics. Data were collected for five countries (Fiji, Samoa, Tuvalu, Vanuatu and Australia) for initial testing. The environmental vulnerability of small island developing states arises from an interplay of factors such as remoteness, geographical dispersion, vulnerability to natural disasters, ecological fragility, a high degree of economic openness and small internal markets, and limited natural resources.

The objective of the project is to promote the use of environmental vulnerability considerations in national development planning and thereby encourage sustainable development. The

Environmental Vulnerability Index (EVI) provides a relatively quick and inexpensive way of characterizing the vulnerability of natural systems at the level of a region, state, province or island.

The figure below shows the scores obtained by Fiji for each of the 47 indicators in the EVI. Areas of vulnerability can be easily identified, information that could lead to better management and possibly better vulnerability scores in the future. A score of 1 is the least vulnerable, 7 the most vulnerable.

Sources: SOPAC 1999 and 2000, Kaly and Craig 2000, Pratt and others 2001



the experience or technology to respond to emerging threats.

Conclusions

Levels of risk and associated human vulnerability change over time. In a resilient society, with appropriate interventions, recovery and mitigation can bring vulnerability back to a previous (baseline) level or reduce it to a lower level, but too fast a rate of change may exceed the capacity of the society to adapt. The long-term nature of environmental change may mean that potential future vulnerability is equally as important as present vulnerability. The capacity to adapt may be more important in determining human vulnerability in the long run than the ability to cope with present critical situations.

The degree and extent of vulnerability appears to be increasing because of a combination of such factors as the increasing impact of humans on the environment, reductions in the efficient functioning of ecosystems, the reduced ability of the environment to provide goods and services, growing and more spatially concentrated populations, and increasing human settlement in high risk areas. As human impact on the environment increases, so people's options decrease. Human vulnerability to environmental change thus increases, despite many instances of adequate coping capacity.

Assessments contribute to better-informed decisions on preparedness, mitigation, relief and rehabilitation activities but there is a lag between the time it takes to make such assessments and the optimal response time. There is a growing gap between rapid rates of environmental degradation and the slow pace of social response. This gap threatens to drain the environment of assets and options for future generations and to increase the costs of substitutes for missing resources (Kasperson and others 1999). High priority should therefore be given to rapid assessments of vulnerability and the design of initial protective responses, such as early warning systems, while longer-term remedial measures are put in place. Environmental restoration, with its potential to reduce vulnerability, will thus become an increasingly important component of sustainable development.

The complexity of the change process makes assessing and measuring human vulnerability to long-term or future environmental change highly

speculative and it is hard to determine the kinds of investment that would most effectively deal with the threats in question. A better understanding of the interplay of the social and physical factors that determine human vulnerability needs to be developed to increase the ability to mitigate potentially harmful impacts that arise from environmental change. Cause-and-effect linkages need to be investigated. Systems modelling approaches and sensitivity analysis may help to determine the nature and timing of the most cost-effective measures to anticipate threats where uncertainty and complex relationships are important.

Delaying a response to an environmental threat often stems from uncertainty, or a lack of knowledge. Improving the assessment process can help resolve this although, even when the risks are known, action may not follow. Nevertheless, regional studies suggest that the breakdown in response is more attributable to narrow government policies aimed solely at economic growth, coupled with a lack of political will, government willingness to tolerate damage in marginal areas and among vulnerable peoples, and widespread political corruption than to public apathy or lack of awareness (Kasperson and others 1999). These are all issues to be tackled.

In the recent past, responses to human vulnerability have progressed from single measures to address a single issue (such as controlling floods by building dykes) to the development of a mix of measures serving different purposes (multipurpose dam projects, warning systems, insurance, land use zoning, integrated river basin management). Today, issues are being visualized in the even broader context of sustainable development (Mitchell 2000). To support these new kinds of policy making, approaches need to be even further integrated to improve the chances of capturing all aspects of human vulnerability.

In an increasing number of areas, environmental damage may be irreversible, or restoration and the reduction in threat may require such a long time that accommodation must accompany any remedial measures. Enabling people to adapt to such situations, especially where change may accelerate in the future, should accompany short-term disaster prevention and management measures. Adaptation is vital where the impacts to which people are vulnerable appear inevitable.

A framework for assessing risk

In 1987, the World Commission on Environment and Development called for the:

- identification of critical threats to the survival, security or well-being of all or of a majority of people, globally and regionally;
- assessment of the causes and likely human, economic and ecological consequences of those threats, with regular and public reporting of the findings;
- provision of authoritative advice on what must be done to avoid, reduce, or adapt to these threats; and
- provision of an additional source of advice to governments and intergovernmental organizations on policies and programmes to address these threats.

Since the report of the Commission was published, IPCC has set up a vulnerability task group, and the System for Analysis, Research and Training (START) and the Project on Critical Environmental Zones were initiated. These studies demonstrated that the coping capacity of countries differs considerably. IPCC claims that vulnerability and coping capacity are inversely related and socially differentiated.

Sources: WCED 1987, IPCC 1996

Stakeholder participation is important in responding to human vulnerability, both to ensure a 'reality check' on coping capacity and to boost prospects of success by involving as many stakeholders as possible in implementing coping mechanisms (IFRC 1999). Stakeholders should review and strengthen their capabilities in the areas of

preparedness and mitigation to increase coping capacities, and become involved in post-event examination of new initiatives that might reduce losses in the future. Communities with effective mitigation strategies could look into ways to help other populations at risk from similar threats. In all cases, assessments of community conditions should provide decision-makers with all the relevant information they need to make strategic decisions to counter vulnerability.

This consideration of human vulnerability has demonstrated that the continuing loss of environmental defences and accelerating global change are increasing threats to human well-being and are putting sustainable development at risk. The evidence suggests that many areas of the world are on trajectories that will lead them into crisis and that little time is left for creating effective responses if deteriorating situations are to be stabilized (Kasperson and others 1999). People are less and less the helpless victims of 'acts of God' and more and more the victims of 'acts of man'. But an increasing understanding of environmental processes and a growing capacity for early warning should help to identify threats and risks and react appropriately. There are now also better means of preventing and reducing harm to people and damage to economies and communities. An increased investment now in sound environmental management, community preparedness and vulnerability reduction will result in important savings in the future.

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