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THE CHANGING CLIMATE AND COMMUNITY VULNERABILITIES TO DISASTERS

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ABSTRACT: Evidence from around the world indicates that the costs of weather related disasters are increasing over time. In many cases, these weather related disasters have resulted from the failure of our infrastructure and built environment to cope with extreme weather events, environmental degradation and the location of infrastructure in high risk locations. While debate still continues on whether or not climate variability and weather extremes have increased, other evidence suggests that vulnerabilities to climate events likely have increased. Reducing societal vulnerability to weather related disasters under current and changing climate conditions will require a diverse and interconnected range of adaptive actions. These actions include hazard identification and risk assessment, comprehensive disaster management, improved predictions of high impact weather, better land use planning, strategic environmental and ecosystem protection, continuously updated and improved climatic design values for disaster resistant infrastructure codes and standards, more enforcement of building codes and improved structural design methods and materials. Steps taken today to reduce the impacts of weather hazards will provide new opportunities to learn how to better face the challenges of the future. While several adaptation steps, both structural and non-structural, can be undertaken today to ensure that communities can withstand the climate of the future, other adaptation actions will be limited by considerable uncertainty in projections on future extremes and by the difficulties of retrofitting or changing the existing built environment.

Keywords: built environment, climate change, disaster, extreme weather, hazard, management, vulnerability.

1. Introduction

One of the most threatening aspects of global climate change is the likelihood that extreme weather events will become more variable, more intense and more frequent. The Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2001a) states that:

> *"The key features of climate change for vulnerability and adaptability are those related to variability and extremes, not simply changed average conditions. Most sectors and regions are reasonably adaptable*

to changes in average conditions, particularly if they are gradual. However, these communities are more vulnerable and less adaptable to changes in the frequency and/or magnitude of conditions other than average, especially extremes". (Chapter 18, page 879)

International concern over extreme weather events has grown as the economic damages and human tolls from these events have increased. Since the decades of the 1950s, the annual direct losses from natural catastrophes have increased 14 times from the 1990s, increasing from US$3.9 billion to US$40 billion a year in 1999 dollars, as shown in Figure 1 (Munich Re, 2000; IPCC, 2001a). Most of these increases in losses have come from weather-related high impact events (Munich Re, 2000; IPCC, 2001a), with a significant proportion of these annual direct losses resulting from the failure of infrastructure or assets in the hazard-affected area to withstand extreme weather or anomalous climate events or from infrastructure and communities located in "harm's way". Of the annual total direct losses averaging $40 billion a year, approximately $9.6 billion of direct damage occurred as a result of damaged to infrastructure (Freeman and Warner, 2001).

While it is normal to expect large year-to-year variations in the number and intensity of natural hazards, it is not normal for the costs of natural hazards to continue rising over time. Several factors in addition to regional climate hazards have contributed to these rising trends in disaster losses (IPCC, 2001a), including:

- increasing populations;
- increasing urbanization and dependence on uninterrupted services in communities;
- increasing prosperity and insured property in developed countries;
- an increasing dependence in developed countries on high technology computer-based technologies and just-in-time delivery systems that are vulnerable to interruptions;
- infrastructure sited in higher risk locations;
- an aging infrastructure, changes to the design of infrastructure (e.g. performance based design) and a highly competitive construction industry;
- increasing poverty in lesser developed nations, ensuring that vulnerable populations remain unable to remove themselves from high risk locations;
- regional environmental degradation, which can transform a climatic hazard (e.g. heavy downpour) into a disaster;

- regional increases in frequencies or intensities of extreme events;
- failure to use best climatic design hazard information as well as best mitigation and engineering practice (including enforcement of codes and standards).

While natural hazards, including hurricanes, flash floods, severe winter storms, windstorms and earthquakes, are inevitable over time, community vulnerability to hazards can almost always be within control. When a natural hazard becomes a disaster and leads to disruptions of entire communities, the result is as much as function of the way that the community does business and adapts to the hazard as it is of the natural hazard itself. A natural hazard

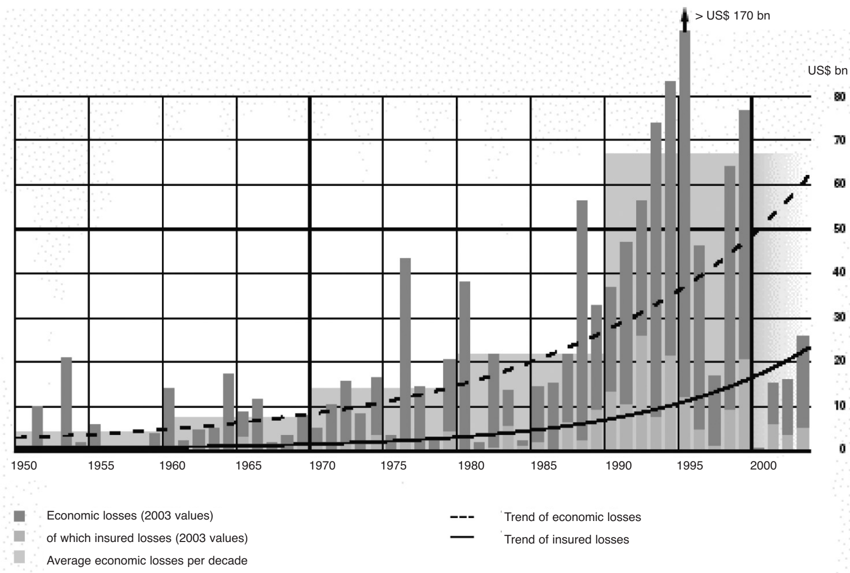

FIGURE 1

Losses from "great" natural disasters from 1950-2000 (US$), including trends in insured and other economic costs.

(From IPCC 2001a and Munich Re 2000). *The costs of catastrophic weather events have exhibited a notable upward trend in recent years. Yearly economic losses from these large disasters increased 10.3-fold from US$3.9 Billion in the 1950s to US$40 Billion per year un the 1990s (expressed in 1999 US$). Costs are larger by a factor of two when losses from relatively ordinary weather-related events are included. Population grew by one 2.4-fold during this period.*

does not need to become a disaster if the risks associated with the hazard are managed. In the built environment, natural hazards can be managed through proper land use, good engineering design and practice, and planned response to timely and accurate weather warnings (Freeman et al, 2003).

2. Managing Disaster Risks for Current and Future Climates

As temperatures warm globally and the climate changes, it is projected that direct losses from extreme weather will increase dramatically with the shifting of storm tracks and regionally increasing storm frequencies and intensities. According to the Intergovernmental Panel on Climate Change (IPCC, 2001a), extreme weather events may occur more frequently, with the potential to affect flooding, droughts and the frequency and severity of cyclonic systems (including hurricanes and tropical storms). Storm impacts in coastal areas will be further impacted by rising sea-levels that will magnify the impact of storm surges and wave action. As total direct damages increase globally, it is reasonable to expect that infrastructure damage as a portion of those overall losses will increase as well. According to a report by the United Nations Environment Programme's (UNEP) financial services initiative, the global cost of natural disasters is anticipated to top US$300 by the year 2050 (Berz, 2001) if the likely impacts of climate change are not countered with aggressive disaster reduction measures. The report calculates potential losses in such areas of energy, water, flood protection efforts, ecosystems vital for fish supplies, agriculture and forestry, construction, transportation, and tourism. In addition to the impacts of climate change, the risks posed by the increasing degradation of the environment, including deforestation, loss of biodiversity, reduced water quality and supply and desertification, can only add to future impacts.

There is a need for more comprehensive and integrated approaches to hazard risk management. These approaches need to accommodate both climate change adaptation requirements and community needs for risk management. All too often, the disaster management disciplines and the climate change disciplines do not communicate with each other, perhaps because the professionals working in these topic areas operate with different timescales and under different mandates. For example, while emergency coordinators focus on real-time disaster events and planning for emergency responses, the climate change scientists have a tendency to work with 50 to 100 year climate models that sometimes may bear little immediate relevance to the policy makers and fieldworks concerned with potential emergencies. The two sets of professionals need to interact more effectively and to better include the planning and development disciplines.

While adaptation actions are known and available today to reduce the risks of current and future natural disasters, many of these adaptation actions have yet to be applied to today's hazard problems for a number of reasons, including capacity and resources. As a first step to reducing climate change disaster risks, a "no regrets approach" that reduces vulnerability to near-term hazards is an effective strategy for reducing long-term risks. Approaches that address the potential impacts of climate change must be based on the current capacity to address existing climate variability and deficiencies in these capacities. Strategies to address existing risk scenarios have the advantage of being more feasible for mobilization of national and international political and financial resources than strategies that address a hypothetical future scenario. The adaptation lessons that are learned in the process of addressing current deficiencies will be needed as risks become more complex under the changing climate. Medium and long-term adaptation must start with efforts to improve current risk management and adaptation.

The first important step in reducing risks under the changed climate is to first seek to identify gaps in current capacity. The barriers to managing the risks associated with current climate variability are the same barriers that will inhibit regions and nations in addressing the future increases in the complexity and uncertainty of risk due to climate change. (UNDP, 2002). As a result, the adaptation lessons learned from current practices, along with a commitment to forensic studies and learning from failures, will constitute a critical component of climate change adaptation. Since many of the impacts of climate change will lie outside of existing experience and existing coping ranges, it is even more important that existing "adaptation deficits" (Burton, forthcoming) first be understood and filled.

3. Disaster Management

3.1 Disaster Management Strategies

Disaster management encompasses a variety of measures taken before, during and after disasters; it denotes the management of disaster risks as well as the consequences of disasters (Freeman et al, 2003). By definition, a hazard is an event or phenomenon that has the potential to cause harm or loss (Asian Disaster Preparedness Centre, 2000) and includes hurricanes, tornadoes, heavy rainfalls, severe ice storms, wind storms and similar events and well as technological accidents (often triggered by climate hazards). A risk is "the probability of harmful consequences, or expected loss resulting from interactions between natural hazards and vulnerable or capable conditions", and a disaster is understood as "the actual impact causing widespread losses which exceed the ability of the affected community/society to cope with such a situation using its own resources" (ISDR 2002). Disaster management then is the planned development and application of policies, strategies and practices to reduce disaster risk. Disaster management in essence tries to minimize the existing vulnerability and to prevent or to limit adverse impacts of hazards (mitigation and preparedness) with comprehensive plans to react to emergencies and act after disaster impacts (rehabilitation and reconstruction) (ISDR, 2002a). Disaster management is the most proactive and successful method for reducing the physical, financial, and emotional losses caused by disasters.

In most countries, natural hazard policies traditionally focus on establishing efficient disaster response. Although disaster response is important, it fails to address the causes of disaster losses. Those causes are rooted in the complex interaction of human settlement and the natural environment. Recurring natural events become disasters because populations exist in harm's way in structures inadequately prepared to withstand anticipated natural hazard events. To protect people and their assets, natural disaster policies must deal with a broad set of issues.

The most important element of a national disaster management plan is prevention. Prevention includes steps to reduce vulnerabilities that cause damages in the first place. Other elements of a disaster management plan include better early weather warnings of impending disasters that buy time to evacuate populations, reinforce infrastructure, reduce potential damages or prepare for emergency response. But, weather warnings are only effective if accompanied by more effective hazard and disaster response policies. In many countries, weather warning systems consist of an escalating series of messages intended to alert the public to impending weather hazards of various magnitude. Typically, these warning systems consist of advisories or watches for potential hazardous weather and then warnings issued as hazardous weather becomes more certain. In the UK, for example, a variety of weather warnings are issued, including early warnings for emergency authorities, motoring warnings for both emergency authorities and the public and warnings of severe weather and of exceptionally severe weather (http://www.met-office.gov.uk/weather/europe/uk/warnings.html). Advance warnings for emergency authorities and escalating warnings of exceptionally severe weather, particularly if linked to potential for infrastructure failure and emergency events, may be required under increasing disaster risks for optimal emergency response and preparedness.

A national disaster system requires the interaction of governments, institutions, financial mechanisms, regulations, and policies. Successful disaster reduction systems involve a wide variety of stakeholders. The most successful systems take advantage of the existing government structures and policies and involve all levels of government and other institutions (*ISDR, 2002a,* 2002b; ISDR, 2004). Above all, a disaster management plan needs to be appropriate for each country's circumstances and economy. The challenge in disaster management is to construct a program that is viewed as more desirable than the status quo by key parties. There also needs to be recognition that programs in place prior to a disaster may be greatly modified after a catastrophe occurs. (UNDP, 2004)

Finally, legislation increases the likelihood that a national disaster management plan will become sustainable. Legislation provides a formal basis for counter-disaster action, allocates major responsibilities in legal form, and provides a measure of protection for governments, organizations, and individuals by outlining the limited responsibilities of each in the disaster management process (Asian Urban Disaster Mitigation Program 2002). But, the best laws are useless if not effectively and impartially enforced.

Repeatedly, history shows that the prevention of natural disasters is closely tied to measures to protect the quality of environments and management of natural resources (German Committee for Disaster Prevention, 2002). At the same time, when disasters are not managed, the resources are often not there either to protect the environment or to ensure that a viable economy is in place. The natural environment can provide valuable environmental services that increase protection against disaster impacts. As a result, successful disaster reduction strategies need to enhance environmental quality, including protection of natural resources and open space, management of water run-off, and reduction of pollution. According to J. Abramovitz (2001), unhealthy ecosystems can exacerbate some hazards to the point where

> *"a growing share of the devastation triggered by 'natural' disasters stems from ecologically destructive practices and from putting ourselves in harm's way. Many ecosystems have been frayed to the point where they are no longer resilient and able to withstand natural disturbances, setting the stage for 'unnatural disasters' – those made more frequent or more severe due to human actions. By degrading forests, engineering rivers, filling in wetlands, and destabilizing the climate, we are unravelling the strands of a complex ecological safety net."*

3.2 Disaster Management Phases

There are two phases to disaster risk management: (1) actions required in the pre-disaster phase and (2) actions needed in the post-disaster period. The pre-disaster phase includes risk identification, risk mitigation, risk transfer, and preparedness; the post-disaster phase is devoted to emergency response and rehabilitation and reconstruction (Freeman et al, 2003).

3.2.1 Pre-Disaster Strategies

In disaster language, mitigation refers to policies and activities that reduce an area's vulnerability to damage from future disasters. These include structural and nonstructural measures that are put into place before a disaster occurs.

3.2.1a Structural Disaster Mitigation Measures

Structural disaster mitigation measures reduce the impact of hazards on people and buildings via engineering measures. Underground electrical transmission lines, for example, are protected from hurricane damage. Levees, dams, and channel diversions are all examples of structural flood mitigation. While structural mitigation projects can be very successful from a cost/benefit perspective, they also have the potential to provide short-term protection at the cost of long-term problems. In some areas, flood control systems have exacerbated rather than reduced the extent of flooding. In one case, sediment deposit in river channels as a result of flood control systems raised the height of river channels and strained dike systems, resulting in flood events of greater depth and bringing more damaging than in the past (Benson 1997). More generally, though, some structural mitigation projects have the potential to provide people with a false sense of security. The damages from the 1993 flooding of the Mississippi river in the United States were magnified because of misplaced confidence in structural mitigation measures that had encouraged development in high-risk areas (Mileti D., 1995; Platt R., 1999). To avoid this problem, structural mitigation projects should be accompanied by appropriate land-use planning and public awareness programs. However, the difficult reality is that land-use planning requires intense political support, particularly if it affects property values or involves the relocation of communities.

3.2.1b Non-Structural Disaster Mitigation Measures

Nonstructural disaster mitigation measures are non-engineered or institutional activities that reduce the intensity of hazards or vulnerability to hazards. Examples of nonstructural mitigation measures include land use management, zoning ordinances and enforcement of building codes, public education and training, and reforestation in coastal, upstream, and mountain areas. Nonstructural measures can be encouraged by government and private industry incentives, including measures such as preferential tax treatment or adjusted insurance premiums that reward private loss-reducing measures (Freeman et al, 2003). Nonstructural mitigation measures can be implemented by central authorities through legislating and enforcing building codes and zoning requirements or by NGOs or community groups initiating neighborhood loss-prevention programs.

The development of good engineering codes and standards will continue to be successful in preventing much harm to the built environment. Codes and standards are intended to represent minimum requirements for safe construction of structures and require the use of climatic and seismic design values. These climatic design values reflect an acceptable risk against the extremes of nature. Quantities like the 10, 30, or 100 year worst storm wind or rainfall are used and these values vary considerably from one location to another (Canadian Commission on Building and Fire Codes, 1995).

A drawback to such measures, however, is that even when they exist, there can be a tendency on the part of the private and public sectors to not properly enforce the regulations or standards on the books. For example, in Florida, insured property losses from Hurricane Andrew would have been reduced by 25 percent through building code compliance (Freeman et al, 2003). Studies have found that inspection personnel sometimes have insufficient knowledge of the hazard mitigation aspects of the building codes to enforce them effectively. The problem is compounded because of limited staffing so that even competent individuals cannot keep up with the demand for building inspections.

3.2.2 Post-Disaster Strategies

A tool for disaster reduction is *preparedness*, which involves the development of an emergency response and management capability long before a disaster occurs. Emergency response refers to actions taken immediately before, during, and after the onset of a major disaster or large-scale emergency to minimize the loss of life and harm to people and their property and enhance the effectiveness of recovery. Key disaster preparedness activities include hazard detection and warning, evacuation of threatened populations, shelter for victims, emergency medical care, search and rescue operations, security and protection of property, family assistance training programs for response personnel, exercises and drills of emergency plans, education programs to inform citizens, hazard detection and warning systems, identification of evacuation routes and shelters, maintenance of emergency supplies and communications systems, establishment of procedures for notifying and mobilizing key personnel, and individual household measures such as clearing attic space to make room for belongings in case of a flood. Other examples include the construction of temporary levees, closure of roads or bridges, provision of emergency water or power supplies, and response to secondary hazards such as fire or the release of hazardous materials.

The quality and timeliness of disaster response are typically functions of the planning and training done during pre-disaster preparedness. From decades of experience, it is clear that the best emergency response comes immediately and with sufficient resources to limit the loss of life and property. Experience in numerous disasters reveals the need for a strong, centralized system to mobilize emergency efforts and channel aid resources to victims (Red Cross, 2001).

In contrast with other elements of disaster management strategies that often operate at the national or large-scale regional level, preparedness projects tend to be oriented toward the actions of individuals and community organizations. Programs must therefore focus on the community level and a national system should include mechanisms to coordinate with preparedness projects. Disaster preparedness also requires significant political will. According to Smith (1996), "*it ties up facilities and people that are apparently doing nothing, other than waiting for an event that no one wants and many believe will never happen*" It is inherently difficult to maintain impetus for diverting resources into preparedness projects if many years have passed since the last disaster event. Outdated plans and warning systems, however, have the potential of being worse than no provisions at all (Freeman et al., 2003).

3.3 Assessing Vulnerabilities: An Effective Adaptation Strategy

A very critical part of a disaster reduction strategy is the completion of a Vulnerability Assessment. Vulnerability is defined as:

> *The extent to which a community, structure, service, or geographic area is likely to be damaged or disrupted by the impact of a particular disaster hazard, on account of their nature, construction, and proximity to hazardous terrain or a disaster prone area (ADPC 2000).*

Vulnerability assessments identify sources of hazards, vulnerable groups, risks likely and potential interventions. For example, vulnerability assessments identify weather and other types of hazards, identify critical infrastructure at risk to these weather hazards along with vulnerable groups and then develops potential adaptation and prevention interventions.

The identification and prioritization of hazards requires documentation and studies on the probable location and severity of dangerous phenomena such as high impact weather as well as information on the likelihood of their occurring within a specific time period in a given area. These studies rely heavily on available scientific information, including climate and hydrological data and maps; topographic maps, aerial photographs, and satellite imagery. Forensic studies or other historical information, in the form of written reports and oral accounts from long-term residents, can also be used at the community level to help characterize potential hazardous events (Government of Ontario, 2003; Meteorological Service of Canada, 2004). To be most successful, hazard assessment requires sufficient and defensible analyses by experienced scientific teams. Physical vulnerability studies could, for example, analyze impacts on local buildings, infrastructure, and agriculture.

4. International Strategy for Disaster Reduction

In recognition of growing concerns over the rising numbers of natural disasters worldwide, the United Nations is developing an International Strategy for Disaster Reduction (UN ISDR). The Strategy will follow from the recommendations of the 1990s International Decade for Disaster Reduction (1994) and the Plan for the Implementation of the World Summit on Sustainable Development in Johannesburg in 2002. The Strategy will identify specific activities on vulnerability, risk assessment and disaster management. As part of the review process leading to the UNISDR, the ISDR Secretariat and the United Nations Development Program (UNDP) have developed a *Framework for Monitoring and Guiding Disaster Reduction*. The framework contains the following goals (ISDR 2002; ISDR 2004):

1. Ensure that disaster risk reduction is a national/regional priority (e.g. legislation, empowering of communities)
2. Identify, assess and monitor risks and enhance early warning (e.g. hazard and risk mapping, climate change trends, weather and early warning systems, risk assessments, disaster information systems).
3. Use knowledge and education to build a culture of resilience (e.g. disseminated information on disaster risks, training for communities, communication technology).
4. Reduce the underlying risk factors (e.g. urban disaster risk assessments, climate variability and change adaptation, protection of critical infrastructure).
5. Strengthen disaster preparedness, contingency planning and community involvement in risk reduction (e.g. update disaster preparedness plans, cooperation between emergency management and disaster risk reduction programs).

5. Implementing a Disaster Management Strategy: A Case Study for Ontario, Canada

The province of Ontario, located in central Canada, passed provincial legislation in April, 2003 requiring that all municipal and regional governments adopt disaster management planning by the end of 2006. The requirements of this legislation meet many of the goals of the International Strategy for Disaster Management. For example, the legislation requires that municipalities identify and assess the various hazards and risks to public safety that could give rise to emergencies in their communities and develop a prioritized emergency response plan, including the identification of the facilities and other elements of the infrastructure that are at risk of being affected by emergencies. In the subsequent two years, these municipalities must develop comprehensive plans to reduce prioritizes risks. This includes the development of a municipal disaster mitigation strategy, planning for high risks, the development of an emergency recovery plan, implementation of guidelines for risk-based land use planning and development of public education programs (Government of Ontario 2003). In support of these measures, Emergency Management Ontario has provided vulnerability assessment training to emergency coordinators while the Meteorological Service of Canada has prepared hazards documentation.

The Meteorological Service of Canada has developed an atmospheric hazards publication and web site that allows municipalities to access climatological information, customize atmospheric hazards maps for their localities and to overlay regional combinations of hazards maps (Meteorological Service of Canada, 2004). The web site includes documentation and a collection of atmospheric hazards maps on a wide range of weather hazards. These maps also include weather hazards maps (e.g. severe ice storms, heat, tornadoes, heavy rainfalls) as well as information on extreme air quality events to help health units develop plans to protect the most health vulnerable members of society. The software on the site allows various hazards maps to be overlain with customized screening criteria applied to each map (see Figure 2). This co-recognition software is helpful in assessing cumulative hazards. Plans are in place to augment the hazards web site with web-based studies on climate change trends, along with information on their potential impacts and implications for future disasters. The site should eventually include displays of customized weather data and weather warning status information, forensic meteorological studies as well as atmospheric risk assessment studies, as appropriate.

FIGURE 2

Composite mapping of two hazards fields: High Hail Frequencies for all locations in Ontario and High Tornado Frequencies. (From http://www.hazards.ca).

6. Conclusions

Since their first appearance on the planet, humans have been adapting to changing climate conditions and to extreme events. But, the growing increases in disasters and losses from climate related hazards indicates that existing adaptation measures have either not been implemented or are failing. These vulnerability and loss trends, combined with new risk factors such as climate change and globalization, all suggest continued increases in losses in the future if deliberate, co-ordinated and conscientious disaster management actions are not taken in the short and medium terms.

There is a growing awareness of the need for linkages between disaster management and climate change. Addressing and managing climate risk in the here and now for current extreme events and impacts is the most appropriate way of strengthening adaptation capacities to deal with changing climate of the future (UNDP, 2002). The adaptation and disaster management options in the here and now must include early warning systems, more accurate forecasting and better uptake of warning information, improved land-use planning and zoning; continuously updated building codes and infrastructure standards; better disaster mitigation planning strategies (including floodplain and other hazard mapping); inventories of resources (such as water) and the use of water-saving devices and watershed management; the inclusion of traditional knowledge; and the integration of climate change considerations into the management decisions for all sectors.

The inappropriate use of natural resources, environmental degradation and haphazard development of human communities are significant contributory factors to natural disasters. Environmental degradation can increase the intensity of natural hazards, or transform a climate hazard into a disaster. The resilience of communities to climate and other hazards can be increased through practices such as the sustainable and integrated management of natural resources, including reforestation schemes, proper land use and good management of rivers and coastal areas (ISDR, 2003). In the end, "secure societies are those that have learned to live with their land as well as from it. Disaster reduction strategies will have succeeded when governments and citizens understand that a natural disaster is a failure of foresight and evidence of their own neglected responsibility rather than an act of God." (ISDR, 2002b).

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