Chapter 9. Case Studies

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9.1 Introduction

In this chapter, case studies are used as examples of how to gain a better understanding of the threats posed by extreme climate-related events while identifying lessons and best practices from past responses to such occurrences. The case studies were chosen to be illustrative of a range of extreme events while also considering some generally vulnerable areas as well as methodological approaches. The case studies examining specific extreme events are: urban heat waves; droughts and associated dust storms; cyclones; and floods. Hazards often occur in complex combinations and these are demonstrated through examples of: complex hot situations with heat and wildfire; complex cold impacts in Mongolia and the Canadian Arctic; and health risks using cholera as the example. As Chapter 3 has projected that many extreme climate events will increase in frequency and/or magnitude in many regions of the world, there is need for early warning systems which are a common adaptation approach to reduce loss. A case study on cities and less-developed small-island states illustrates specific examples of vulnerability. Risk transfer, legislation and governance and education are presented as examples of methodological ways of climate change adaptation and disaster risk reduction. This selection provides a good basis of information and served as an indicator of the resources needed for future disaster risk reduction. Additionally, it allows good practices to be determined and lessons to be extracted. The case studies provide the opportunity for connecting common elements across the other chapters.

Case studies are widely used in many disciplines including health care (Keen and Packwood, 1995; McWhinney, 2001) social science (Flyjberg, 2004), engineering, and education (Verschuren, 2003). In addition case studies have been found to be useful in previous Intergovernmental Panel on Climate Change (IPCC) Assessment Reports including the 2007 report (Parry *et al.,* 2007). Case studies can be records of innovative or good practice. Specific problems or issues experienced can be documented as well as the actions taken to overcome problems. Case studies validate our understanding or can encourage their re-evaluation and it is important that there be a good theoretical basis arising from application of rigorous methodology and comparative multi-case logic (Eisenhardt, 1989). From the work of Grynszpan *et al*. (2011) it is apparent that:

- Case studies capture the complexity of disaster risk and disaster situations;
- Case studies appeal to a broad audience; and
- Disaster reduction needs to make the most of each single case.

The case studies included in Chapter 9 have been prepared from a variety of literature sources prepared in many disciplines. As a result an integrated approach that examines scientific, social, economic and political aspects of disasters and includes different spatial and temporal scales is needed. The specialized insights they provide are invaluable in evaluating some current disaster response practices.

This chapter addresses events whose impacts were felt on many dimensions. A single event can produce effects that are felt on local, regional, national and international levels. These could have resulted directly from the event itself, from the response to the event or through the indirect impact of, for example, the reduction of food production in the region or a decrease in available resources. In addition to the spatial scales, this chapter also addresses temporal scales which vary widely in both event-related impacts and responses. However, the way effects are felt is additionally influenced by social and economic factors. The resilience of a society and its economic capacity to prevent a disaster and cope with the after-effects has significant ramifications for the intensity of the event (UNISDR, 2008). Developing countries with less resilient resources, experts, equipment and infrastructure have been shown to be particularly at risk (Chapter 5). Developed nations are usually better equipped with technical, financial and institutional support to enable better adaptive planning including preventative measures and/or quick and effective responses (Gagnon-Lebrun and Agrawala, 2006) . However they still remain at risk of high impact events as exemplified by the European heatwave of 2003 and Hurricane Katrina (Parry *et al*., 2007).

The implications of factors such as location, development status, scale of disaster and response efforts in specialized communities, will make it easier for strategies to be applied in similar situations. Most importantly, this chapter recognized the complexity of disasters in order to encourage more solutions that address this complexity rather than just one issue or another.

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9.2. Cases Studies

Case Study 9.2.1. Cyclones: Enabling Policies and Responsive Institutions for Community Action

<u>Introduction</u>

Tropical cyclones, also called typhoons and hurricanes, are powerful storms generated over tropical and sub-tropical waters. Their impacts include extremely strong winds damaging buildings and infrastructure, torrential rains causing floods and landslides, and high waves and storm surge leading to extensive coastal flooding. An example of the destructive power of a seemingly unremarkable cyclone was the devastation caused by Typhoon Morakot in Taiwan (Lin et al. 2011). On 7 August 2009, Typhoon Morakot, which was classified only as a category 1 cyclone (maximum wind speed was less than 32.6 m/s), made landfall on the east coast of Taiwan. Other than its movement being about 30% slower than an average typhoon and a relatively large wind field radius of about 400 km, Morakot did not show any obvious extraordinary characteristics. However, Morakot set the record for the highest one-day precipitation, continuous two-day precipitation and total accumulation over the duration of a typhoon (3060 mm, from 6 to 10 August 2009) in Taiwan (Lin et al. 2011). The record amount of precipitation caused the worst flooding in Taiwan since 1959 and triggered over 50,000 landslides that seriously damaged nearly all roads in the central and southern mountains of Taiwan. Close to 700 people lost their lives, including 400 inhabitants of a village that was buried by a landslide. Total damages to property and infrastructure, and agricultural losses were estimated to be about US$ 3 billion.

The uncertainties in the historical tropical cyclone records, the incomplete understanding of the physical mechanisms linking tropical cyclone metrics to climate change, and the degree of tropical cyclone variability provide only low confidence for the attribution of any detectable changes in tropical cyclone activity to anthropogenic influences. However, there is medium confidence that the frequency of the most intense storms will increase in some ocean basins and it is likely that tropical cyclone-related rainfall rates will increase with greenhouse warming (see Chapter 3).

Various issues related to the risk management practices and changing temporal and spatial vulnerability of the population exposed to tropical cyclones are discussed in this case study. In particular, the comparative studies clearly demonstrate that efforts towards disaster risk reduction can be effective in the context of adaptation to extreme tropical cyclone events.

Government Policies – Learning from Past Disasters

Dealing with the Tropical Cyclone Risk in Bangladesh

Bangladesh experiences on average a severe tropical cyclone (wind speed 90-120 km/h) every three years (UNDP, 2004; World Bank 2010). Among the many tropical cyclones over the last 4 decades, Bhola in 1970, Gorky in 1991 and Sidr in 2007 proved to be the most severe in terms of their intensity and associated storm surge heights. All these were extreme events but the loss of life has been considerably reduced with each succeeding event as shown in the Table 9-1.

[INSERT TABLE 9-1 HERE:
Table 9-1: Affected people and fatalities caused by tropical cyclones Bhola (1970), Gorky (1991), and Sidr (2007) in Bangladesh.]

The 1970 Bhola cyclone was the deadliest tropical cyclone ever recorded in Bangladesh and one of the most catastrophic disaster events of the 20th century (Haque and Blair 1992, GoB 2008). Although two subsequent cyclones (Gorky in 1991 and Sidr in 2007) had comparable severity in terms of intensity and storm surge, and exposed greater number of people than Bhola, the loss of life for those events was dramatically reduced compared to Bhola.

The key DRR measures that make the national system in Bangladesh increasingly effective against cyclone hazards and associated storm surges may be attributed to three concrete steps taken by the Government in partnership with donors, NGOs, humanitarian organizations and, most importantly, by involving the vulnerable coastal communities themselves.

First, the construction of cyclone shelters in the coastal regions has provided safe refuge for coastal populations. These shelters are multi-storied buildings with capacity for 500 to 2500 people (Paul and Rahman 2006) and are raised on platforms above ground-level to resist storm surges. Also, killas (raised earthen platforms) which usually accommodate 300 – 400 livestock have been constructed in the cyclone-prone areas to safeguard livestock from storm surges (Haque, 1997).

Second, the coastal volunteer network, established under the cyclone preparedness programme (CPP), has proved to be an effective mechanism for dissemination of cyclone warnings among the coastal communities and for time-critical actions on the ground for safe evacuation of vulnerable populations to cyclone shelters (Paul 2009). These volunteers helped to evacuate around 350,000 people to cyclone shelters during Gorky in 1991 and, with a sevenfold increase of cyclone shelters and twofold increase of volunteers; 1.5 million people were safely evacuated prior to landfall of Sidr in 2007.

Third, there has been a continued effort to improve forecasting and warning capacity in Bangladesh. A Storm Warning Center (SWC) has been established in the Meteorological Department and system capacity has been enhanced to alert to a wide range of user agencies with early warnings and special bulletins soon after the formation of tropical depressions in the Bay of Bengal (Chowdhury 2002). Periodic training and drilling practices are conducted at the local level for CPP volunteers for effective dissemination of cyclone warning and for raising awareness among the populations in the vulnerable communities. The key improvements in the above three measures for reducing disaster risks from tropical cyclones in Bangladesh are listed in Table 9-2.

[INSERT TABLE 9-2 HERE:
Table 9-2. Improvements in key measures for reducing risk of tropical cyclones in Bangladesh since 1970.]

Added to these are many other hard and soft measures and local adaptive practices that have contributed to increased resilience of the coastal populations (Paul 2009). The expansion of embankments and reforestation programs along the coasts and offshore islands has reduced the impact of Sidr significantly. Since 1959, more than 5,500 km of coastal embankments has been constructed in the coastal districts to support agriculture and protect crops and properties from saline tidal flooding (GoB 2008). The world's largest mangrove forest, the Sundarbans, lies along the south-western coast of Bangladesh, providing a spatial buffer for population and crops and reducing storm surges energy. Cyclones Bhola and Gorky had landfall in the middle and eastern coast with little or no forest. On the contrary, Sidr had landfall in western coast covered by the Sundarbans, which cushioned and reduced the impacts considerably (Paul 2009). Coastal reforestation has been a priority intervention in the coastal region for reducing the thrust of storm surges and stabilising the coast (Karim and Mimura 2008, World Bank 2010).

The existing number of cyclone shelters and killas in Bangladesh are reported to be far from adequate to accommodate the increasing size of the number of coastal population and assets (GoB 2008, Islam 2004). Sometimes these are located at a distance of more than 3.5 miles (5.6 km) apart. Studies have shown that it is difficult for the coastal populations to take refuge at times of emergency unless the cyclone shelter is located within the proximity of 1 mile (1.6 km) (Paul 2009). Over 1,500 cyclone shelters (40% of total) were damaged by river erosion or abandoned for their dilapidated conditions due to lack of maintenance. Most of the casualties during Sidr occurred in islands where cyclone shelters were non-existent or inadequate in numbers or not in usable condition (GoB 2008). In contrast, all of those who sought refuge in concrete or building structures survived from Gorky in 1991 (Bern et al. 1993). Multi-purpose use of cyclone shelters is now increasingly recognized as an effective way to promote local development as well as to ensure regular maintenance for their effective use during cyclone emergency (Chowdhury 2002).

While the existing risk reduction measures in Bangladesh have achieved significant progress in cyclone preparedness and reduction of mortality, climate change may increase the risk to coastal communities because of the changes in the characteristics of extreme tropical cyclone events and sea level rise (IPCC 2007, Karim and Mimura 2008, Unnikrishnan 2006, Webster 2008). This means that the Government of Bangladesh should pay even more attention to proactive risk reduction measures, building on the experience of what has worked well in the past.

Sidr and Nargis: Comparison of Two Cyclones in Indian Ocean

Although only 15% of the world tropical cyclones occur in the North Indian Ocean (Reale et al. 2009), they account for 86% of mortality risk (ISDR 2009). This is due to the high population density and poor governance in some of the exposed countries in this region.

In 2007 and 2008, several cyclones with disastrous impacts occurred in the North Indian Ocean. Two of these, namely Cyclone Sidr in 2007 (Paul 2009), which mainly affected Bangladesh, and Cyclone Nargis in 2008 (Webster 2008), which mainly affected Myanmar, were comparable events that had vastly different impacts (Table 9-3) Sidr made landfall in Bangladesh on 15 November 2007 and caused about 4,200 fatalities. Nargis hit Myanmar on 2 May 2008 and caused over 138,000 fatalities (CRED 2009), making it the eighth deadliest cyclone ever recorded (Fritz et al. 2009).

[INSERT TABLE 9-3 HERE:
Table 9-3: Characteristics of tropical cyclone Nargis (2008) in Myanmar.]

Bangladesh has a significant historical record of large scale disasters and serious efforts to decrease the risk from tropical cyclones have been made by the Government Bangladesh in the past decades (Paul 2009). In additions to the measures mentioned earlier, a coastal reforestation program was initiated in Bangladesh in 1960, covering about 159,000 ha of coastal land, the riverine coastal belt, and abandoned embankments. The Sunderban mangroves and coastal forests proved to be effective attenuation buffers during Sidr, greatly reducing the impact of the storm surge (GoB 2008).

In contrast to Bangladesh, Myanmar has very little experience with previous powerful tropical cyclones. Prior to Nargis, Myanmar had experienced only one tropical cyclone disaster with more than 1000 fatalities since 1960 (CRED 2009). The landfall of Nargis was the first time in recorded history that Myanmar experienced a cyclone of such a magnitude and severity (Lateef 2009) and “the path of the storm could not have been worse” (Webster 2008). Several unfavourable conditions joined hands to transform this hazardous event into a large scale disaster, the most important of which was the intensity of Nargis. There was virtually no early warning for this event. The Indian meteorological department has the responsibility to issue cyclone warnings for the region, but has no mandate to provide storm surge forecasts (80% of the victims from Nargis were killed by the storm surge). Myanmar's official forecasts appeared on page 15 in the newspaper The New Light of Myanmar (a government-owned newspaper published by the Ministry of information) from 29 April to 2 May, suggesting that the media underestimated the potential impacts of the threat, which resulted in insufficient warning to the population (Webster 2008).

Nargis, despite being both slightly less powerful than Sidr and affecting fewer exposed people, resulted in human losses that were 32 times higher than Sidr. Bangladesh and Myanmar are both very poor countries. In 2008, the estimated Growth Domestic Product per capita in purchasing power parity (GDPppp) for Bangladesh was $1,500, while it was $1,200 for Myanmar (CIA 2009). This relatively small difference in poverty cannot explain the discrepancy in the impacts of these events. The governance indicators developed by the World Bank (Kaufmann et al. 2010) suggest significant differences in the quality of governance between Bangladesh and Myanmar, notably in Voice and Accountability, Rule of Law, Regulatory Quality, and Government Effectiveness. Low quality of governance, and especially Voice and Accountability, was highlighted as a major vulnerability component for human mortality risk to tropical cyclones (Peduzzi et al., 2009).

Stan and Wilma: Comparison of Two Hurricanes in Mesoamerica

Hurricane Stan hit the Atlantic coast of Central America and the Yucatan Peninsula in Mexico (Mesoamerica) between the 1st and 13th of October 2005. It was associated with a larger non-tropical system of rainstorms that dropped torrential rains and caused debris flows, rockslides and widespread flooding. Guatemala reported more than 1,500 fatalities, El Salvador 72 and Mexico 98. Hurricane Wilma hit one week later (October 19-24th), with a diameter of 700km and winds reaching a speed of 280 km/h. It caused twelve fatalities in Haiti, eight in Mexico and thirty five in the USA (National Hurricane Center, April 6, 2006). 560,000 residents in western part of Cuba and tourists and local inhabitants in the Yucatan Peninsula in Mexico were evacuated during this event (EM-DAT 2010).

A joint study by the World Bank with CEPAL and CENAPRED (the National Center for Disasters, García et al., 2006) showed that Stan caused about $2.2 billion damage in Mexico, 65% of which were direct losses and 35% impact on future productive activities (coffee, forestry and livestock). About 70% of these damages were reported in the state of Chiapas (Oswald Spring, 2010).

While Stan mainly hit the poor indigenous regions of Guatemala, El Salvador and Chiapas in Mexico, Wilma affected the international beach resort of Cancun. The damages caused by Wilma were estimated to be $1.74 billion, 25% of which were direct damage and 75% indirect costs due to lost economic opportunities. The damages caused by Wilma were mostly to the tourist sector. However, most of the affected and destroyed hotels were insured.

Comparison of the management of the two hurricanes by the Mexican authorities, in the same month and year, highlights important issues in disaster risk management.

Following the early alert for Wilma, 98,000 people were evacuated, 27,000 tourists were brought to safer places, and 15,000 local inhabitants and tourists were taken to shelters (García et al., 2006). Before the hurricane hit the coast, heavy machines and emergency groups were situated in the region to re-establish water, electricity, communications and health services immediately. After the disaster, all ministries got involved in order to re-establish the airport and tourist facilities as soon as possible. By December, most hotels and the sand lost from the beaches were re-established.

By comparison, the evacuation of Stan in Mexico started during the emergency phase, when floods in 98 rivers had affected 800 communities (Pasch and Roberts, 2006). About 100,000 people fled from the mountain regions; 84,000 were living in improvised shelters -mostly schools- and 1,200 affected families lived with "guest families". In total, about 2 million people in Mexico were affected by this event. Over 80% of the damages were concentrated in four municipalities (Motozintla, Tapachula, Huixtla and Suchiate). They were rural, isolated in mountainous areas, marginal, indigenous, and most inhabitants were extremely poor and had no or scarce education. The cost of damages caused by Stan represented 5% of the GDP of the State of Chiapas and most of the productive infrastructure (75,000 hectares of coffee plantation) in the affected areas was destroyed (Calvillo et al., 2006). Emergency help was brought by ship, plane and cars, but the head of SEDESOL (Ministry of Social Development) in Chiapas, Luis Alberto Molina Rios, had to admit a year later that less than 10% of the 10,200 houses affected by Stan were rebuilt.

Comparing the government responses to these two hurricanes in the same month, it is possible to note vastly different official actions in terms of early warning, evacuation and reconstruction. Federal attention appears to have been focused on Wilma, which affected Cancun, an international beach resort. The tourists and local inhabitants in Cancun were evacuated efficiently, and a massive recovery support strategy restored almost all services and hotels within two months. Meanwhile, the damages inflicted by Stan in the mountain regions of Chiapas were more serious, and the affected population did not have any form of insurance due to their high social vulnerability. The inadequate response to Stan left the poor indigenous groups with limited advice, insufficient disaster relief and scant reconstruction, especially in the highest and most marginal mountain regions.

Concluding Remarks

Comparative studies of the disaster management practices for tropical cyclones demonstrate that the choices and outcomes for response to climatic extremes events are complicated by multiple interacting processes, and competing priorities. The government response to similar extreme events may be quite different in neighbouring countries, or even within the same country.

Tropical cyclone risk management strategies in coastal regions that anticipate and plan for the effective of climate change, along with continuing changes in vulnerability and it causal processes, increase resilience in potentially affected communities. International cooperation and investments in forecasting and implementation of improved early warning systems, evacuation plans, infrastructures, protection of healthy ecosystems, and post-disaster support service to disperse the recovery funds to the victims efficiently are essential in coping with extreme tropical cyclone events.

Climate change adaptation, supported by disaster risk management, is most effectively pursued by understanding the diverse ways in which social processes contribute to the creation, management, and reduction of disaster risk. For developing countries, understanding and managing disaster risk from a development and development planning perspective is the key to a coherent strategy for climate change adaptation and disaster risk reduction.

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Case Study 9.2.2. Urban Heatwaves – The European Heatwaves of 2003 and 2006

Background

Extreme heat is a prevalent public health concern throughout the temperate regions of the world (Kovats, et al. 2008). Extreme heat hazards have been encountered recently in North America (Hawkins-Bell and Rankin 1994; Klinenberg 2002), Asia (Kalsi and Pareek 2001; Srivastava, et al. 2007; Kumar 1998), Africa (Earth Observatory 2008; BBC 2002), Australia (Victorian Government Department of Sustainability and Environment 2008) and Europe (Robine et al. 2008; Founda and Giannakopoulos 2009), and there is consensus that climate change is very likely to increase the frequency of extreme heat events (SREX chap 3). As with other types of hazards, extreme heat can have disastrous consequences, particularly for very vulnerable populations. Risk from extreme heat is a function of hazard severity and population vulnerability. Extreme hazards do not necessarily translate into extreme impacts if vulnerability is low. It is important, therefore, to consider factors that contribute to hazard exposure and population vulnerability. Recent literature has identified a host of factors that can amplify or dampen hazard exposure. Experience with past heat waves and public health interventions suggest that it is possible to manipulate many of these variables to reduce both exposure and vulnerability and thereby limit the impacts that extreme heat hazards present.

Social and Biological Vulnerabilities to Heatwaves

Several factors influence vulnerability to heat-related illness and death. Most of the research related to such vulnerability is derived from experiences in industrialized nations. Several physiologic factors, such as age, gender, body mass index, and pre-existing health conditions play a role in the body's ability to respond to heat stress. Older persons, babies and young children have a number of physiological and social risk factors that place them at elevated risk, such as decreased ability to thermoregulate (the ability to maintain temperature within the narrow optimal physiologic range) (Havenith 2001). Pre-existing chronic disease, more common in the elderly, also impairs compensatory responses to sustained high temperatures (Havenith 2001; Shimoda 2003). Many older adults tend to have suppressed thirst impulse. In addition, multiple diseases and/or drug treatments also increase the risk of dehydration (Hodgkinson et al. 2003; Ebi and Meehl 2007). Older persons may also be more likely to be isolated and living alone than younger persons (Naughton 2002; Semenza 2005).

A wide range of socio-economic factors is associated with increased vulnerability. Areas with high crime rates, low social capital, and socially isolated individuals increased vulnerability during the Chicago heat wave in 1995 (Klinenberg 2002). People in low socioeconomic areas are generally at higher risk of heat-related morbidity and mortality due to higher prevalence of chronic diseases that increase risk, from cardiovascular diseases such as hypertension to pulmonary disease such as chronic obstructive pulmonary disease and asthma (Smoyer et al. 2000; Sheridan 2003). Minorities and communities of low socio-economic status are more frequently situated in higher heat stress neighborhoods (Harlan et al 2006). Protective measures are often less available for those of lower socioeconomic status, or even if air conditioning is available, some of the most vulnerable populations will choose not to use it out of concern over the cost (O'Neill et al. 2009). Other groups, like the homeless and workers, are particularly vulnerable because of their living and working conditions (Yip et al. 2008).

Impact of Urban Infrastructures

As soon as circumstances permit, by addressing vulnerabilities in urban areas, much benefit will be accrued. About half the world's population lives in urban areas at present, and by 2050, this figure is expected to rise to about 70 percent. Cities across the world are expected to absorb most of the population growth over the next four decades, as well as continuing to attract migration from rural areas (United Nations 2008). In the context of an extreme heat event, certain infrastructural factors can either amplify or reduce the vulnerability of exposed populations. The built environment is important since local heat production affects the urban thermal budget (from internal combustion engines, air conditioners, and other activities), surface reflectivity or albedo, the percent of vegetative cover, and thermal conductivity of building materials. The urban heat island effect, caused by increased absorption of infrared radiation by buildings and pavement, lack of shading and evapotranspiration by vegetation and increased local heat production, can significantly increase temperatures in the urban core by several degrees Celsius, raising the likelihood of hazardous heat exposure for urban residents (Clarke 1972; Shimoda 2003).

Research has also identified that, at least in the North American and European cities where the phenomenon has been studied, these factors can have significant impact on the magnitude of heat hazards on a neighborhood level (Harlan et al. 2006). One study in France has shown that higher mortality rates occurred in neighborhoods in Paris that were characterized by higher outdoor temperatures (Cadot et al. 2007). High temperatures can also affect transport networks when heat damages roads and railtracks. Within cities, outdoor temperatures can vary significantly, some work has found by as much as 5ºC (Konopacki et al. 2001; Rosenzweig and Solecki 2005).

Systems of power generation and transmission partly explain vulnerability since electricity supply underpins air-conditioning and refrigeration, a significant adaptation strategy particularly in developed countries, but one that is also at increased risk of failure during a heat wave. Demand for electricity to power air-conditioning and refrigeration units is likely to increase with rising ambient temperatures. Areas with lower margins face increased risk of disruptions to generating resources and transmission under excessive heat events.

In addition to increased demand, there can be a risk of reduced output from power generating plants (UNEP 2004). The ability of inland thermal power plants, both conventional and nuclear, to cool their generators down is restricted by rising river temperatures. Additionally, fluctuating levels of water availability will affect energy outputs of hydropower complexes. During the summer 2003 in France, six power plants were shut down and others had to control their output (Létard et al. 2004).

<u>Description of the Events</u>

During the first two weeks of August 2003, temperatures in Europe soared far above historical norms. The heatwave stretched across much of Western Europe, but France was particularly affected (InVS 2003). Maximum temperatures recorded in Paris, for example, remained mostly in the range of 35°-40°C between 4th and 12th August, while minimum temperatures recorded by the same weather station remained almost continuously above 23°C between 7th and 14th August (Météo France 2003). The European heat wave had significant health impacts (Lagadec 2004). Initial estimates put the death toll across Europe over the first two weeks of August in the range of 35,000 and costs were estimated to exceed 13 billion euros (UNEP 2004, SREX chap 3), while it has been estimated that mortality over the entire summer could have reached about 70,000 (Robine et al. 2008). There were approximately 14,800 excess deaths in France alone (Pirard et al. 2005). The severity, duration, geographic scope, and impact of the event were unprecedented in recorded European history (Grynszpan 2003; Kosatsky 2005; Fouillet, Rey et al. 2006) and put the event in the exceptional company of the deadly Beijing heat wave of 1743, which killed at least 11,000, and likely many more (Levick 1859; Bouchama 2004; Lagadec 2004; Robine et al. 2008; Pirard et al. 2005). Efforts to minimize the public health impact were hampered by denial of the events' seriousness and the inability of many institutions to instigate emergency-level responses (Lagadec 2004). Afterwards, several European countries quickly initiated plans to prepare for future events (WHO Regional Office for Europe 2006). France, the country hardest hit, developed a national heat wave plan, surveillance activities, clinical treatment guidelines for heat related illness, identification of vulnerable populations, infrastructure improvements, and home visiting plans for future heat waves (Laaidi, Pascal et al. 2004).

Three years later, between 10th and 28th July 2006, Europe experienced another major heat wave. In France, it ranked as the second most severe heatwave since 1950, the most severe having been the one in 2003 (Fouillet et al 2008; Météo France 2006). Although the 2003 heatwave lasted a few days longer than the 2006 one, it was less intense and did not cover as large a geographical area. Across France, recorded maximum temperatures soared to 39°-40°C (compared with 40°-44°C in 2003), while minimum recorded temperatures reached 19°-23°C (compared with 23°-25°C in 2003) (Météo France 2006). Based on a historical model, the temperatures were expected to cause around 6,452 excess deaths in France alone, yet only around 2,065 excess deaths were recorded (Fouillet et al. 2008). The difference in impact between the heatwaves in 2003 and 2006 may be at least partly attributed to the difference in the intensity and geographic scope of the hazard. It has been hypothesised that, in France at least, some decrease in mortality may also be attributed to increased awareness of the ill-effects of extreme heat, the preventive measures instituted after the 2003 heat wave, and the heat health watch system set up in 2004 (Fouillet et al. 2008). While the mortality reduction may demonstrate the effectiveness of public health measures, the persistent excess mortality highlights the need for optimizing existing public health measures such as warning and watch systems (Hajat et al. 2010), health communication with vulnerable populations (McCormick 2010a), vulnerability mapping (Reid, O'Neill et al. 2009), and heat wave response plans (Bernard and McGeehin 2004). It also highlights the need for other, novel measures such as modification of the urban form to reduce exposure (Bernard and McGeehin 2004; O'Neill et al. 2009; Reid, O'Neill et al. 2009; Hajat et al. 2010; Silva et al. 2010).

Interventions

Adapting the Urban Infrastructure

Several types of infrastructural measures can be taken to prevent negative outcomes of extreme heat events. Models suggest that significant reductions in heat-related illness would result from land use modifications that increase albedo, proportion of vegetative cover, thermal conductivity, and emissivity in urban areas (Silva et al. 2010; Yip et al. 2008). Reducing energy consumption in buildings can improve resilience, since then localized systems are less dependent on vulnerable energy infrastructure. In addition, by better insulating residential dwellings, people would suffer less effect from extreme heat. Financial incentives have been tested in some countries as a means to increase energy efficiency by supporting people who are insulating their homes. Urban greening can also reduce temperatures, protecting local populations and reducing energy demands (Akbari 2001).

Public Health Approaches to Reducing Exposure

The risks associated with extreme heat hazards can be reduced by lowering the likelihood of exposure and reducing vulnerability. A common public health approach to reducing exposure likelihood is the Heat Warning System (HWS) or Heat Action Response System (HARS). The four components of the latter include an alert protocol, community response plan, communication plan and evaluation plan (Health Canada 2010). The HWS is represented by the multiple dimensions of the EuroHeat plan, such as a lead agency to coordinate the alert, an alert system, an information outreach plan, long-term infrastructural planning, and preparedness actions for the healthcare system (WHO 2009). There are a range of approaches used to trigger alerts and a range of response measures implemented once an alert has been triggered. In some cases, departments of emergency management lead the endeavour, while in others public health-related agencies are most responsible (McCormick 2010b).

There is very limited evidence on the effectiveness of the heat warning systems. A few studies have identified a reduced impact. For example, the use of emergency medical services during heatwave events dropped by 49% in Milwaukee, Wisconsin between 1995 and 1999, but this was not entirely attributable to differences between two heat waves in those years (Weisskopf et al. 2002). Evidence has also indicated that interventions in Philadelphia may have reduced mortality rates by 2.6 lives per day during heat events (Ebi et al. 2004). An Italian intervention program found that caretaking in the home resulted in decreased hospitalizations due to heat (Marinacci et al. 2009). However, for all these studies, it is not clear whether the observed reductions were due to the interventions. Questions remain about the levels of effectiveness in many circumstances (Cadot 2007).

Heat preparedness plans vary around the world. Philadelphia, Pennsylvania, one of the first US cities to begin a heat preparedness plan, has a ten-part program that integrates a "block captain" system where local leaders are asked to notify community members of dangerous heat (McCormick 2010b; Sheridan 2006). Programs like the Philadelphia program that utilize social networks have the capacity to shape behavior since networks can facilitate the sharing of expertise and resources across stakeholders, but may also contribute to vulnerability (Crabbé and Robin 2006). Other heat warning systems, such as that in Melbourne, Australia, are based solely on alerting the public to weather conditions that threaten older populations (Nicholls et al. 2008). In Canada, a HARS was developed through participatory processes, including 1) community HARS Advisory Communities (2) conducting heat health vulnerability assessments, 3) conducting extreme heat simulation exercises (4) developing HARS communications strategies and 5) evaluating the systems (reference?).

Addressing social factors in preparedness promises to be critical for the protection of vulnerable populations. This includes incorporating communities themselves in understanding of and responses to extreme events. Top-down measures imposed by health practitioners that do not account for community-level needs and experiences are likely to fail. Greater attention to and support of community-based measures in preventing heat mortality can be more specific to local context, such that participation is broader (Semenza 2006). Such programs can best address the social determinants of health outcomes.

Communication and Education

One particularly difficult aspect of heat preparedness is communicating risks. In many locations populations are unaware of their risk and heatwave warning systems go largely unheeded (Luber and McGeehin 2008). Some evidence has even shown that top-down educational messages result in a very limited amount of resultant action (Semenza et al. 2008). The receipt of information is not sufficient to generate new behaviors or the development of new social norms. Even when information is distributed through pamphlets and media outlets, behavior of at risk populations often does not change, and those targeted by such interventions have suggested that community-based organizations be involved in order to build on existing capacity and provide assistance (Abrahamson, Wolf et al. 2008). Older people, in particular, engage better with prevention campaigns that allow them to maintain independence and do not focus on their age, as many heat warning programs do (Hughes et al. 2008). Older adults may depend on numerous tools and strategies to address their special needs (Aldrich and William 2008). More generally, research shows that communication about heat preparedness should be centered around engaging with communities in order to increase awareness (Smoyer-Tomic and Rainham 2001).

Assessing Heat Mortality

Assessing excess mortality related is the most widely used means of assessing the health impact of extreme heat events. Mortality is likely to represent only the 'tip of the iceberg' of heat-related health effects; however it is more widely and accurately reported than morbidity, which explains its appeal as a data source. Nonetheless, assessing heat mortality presents particular challenges. Accurately assessing heat-related mortality faces challenges of differences in contextual variations (Poumadere et al. 2005), (Hémon and Jougla 2004), and coroner's categorization of deaths (Nixdorf-Miller et al. 2006). For example, there are a number of estimates of mortality for the European heat wave that vary depending on geographic and temporal ranges, methodological approaches, and risks considered (Assemblee-Nationale 2004). The different types of analyses used to assess heat mortality, such as certified heat deaths and heat-related mortality measured as an excess of total mortality over a given time period, are important distinctions in assessing who is affected by the heat (Kovats and Hajat 2008). Learning from past and other countries' experience, a common understanding of definitions of heatwaves and excess mortality, and the ability to streamline death certification in the context of an extreme event could improve the ease and quality of mortality reporting.

Lessons Identified and Concluding Remarks

With climate change, heatwaves are very likely to increase in frequency and severity in many parts of the world (SREX chap 4). Urban settings are especially susceptible to heatwaves, even and possibly more so in highly developed countries. Smarter urban planning, improvements in existing housing stock and critical infrastructures and effective public health measures will assist in facilitating climate change adaptation.

Disaster risk originates from a combination of social processes and their interaction with the environment. Social, biological, built environmental and infrastructural characteristics shape vulnerability to extreme heat events.

With understanding of local conditions and experiences and current and projected risks, it will be possible to develop strategies for improving disaster risk reduction in the context of climate change.The specificity of heat risks to particular sub-populations can facilitate appropriate interventions and preparedness.

Further research is needed on the effectiveness of existing plans, how to develop improved preparedness that specifically focuses on vulnerable groups, and how to best communicate heat risks across diverse groups. There are also methodological difficulties in describing individual vulnerability that need further exploration.

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Case Study 9.2.3. Drought, Its Effects and Management

<u>Introduction</u>

Droughts have been a part of our environment since the beginning of recorded history, and humanity's survival may be testimony only to its capacity to endure this climatic phenomenon. Drought is considered by many to be the most complex but least understood of all natural hazards, affecting more people than any other hazard (Hagman 1984). As drought has different types and different impacts based on geographic locations, examples of the complex ways in which extreme events, long term trends, and high vulnerability interact to produce extreme impacts in different geographical locations.

Drought in the Sahel

Sahel is located on the southern margins of the Sahara desert, reflecting the zone where the ecology and the climate start to make settlement possible again (Nyong et al., 2007). Prolonged periods of drought in the Sahel have been experienced throughout the past 5,000 years of agriculture, reflecting the way in which the southern boundary of the desert fluctuates. After two decades of wet conditions in the 1950s and 1960s, the most significant severe drought was in the early 1970s (Hulme, 1992, 1996, 2001, Batterbury and Warren, 2001).

The severe drought 1970-1990 made the society and ecosystems more vulnerable to impacts from extreme events (Mortimore, 1998), and at the same time the Sahelian population increased rapidly with an average annual growth of 2.6 percent (UNPP, 2006). This increase appears to be a main cause of degradation of ecosystems by humans with over –use of natural resources in the region through overgrazing, deforestation, over-cultivation, intensive irrigation, and poor land management (Olsson et al. 2005, Ezra, 2001, Nicholson, et al. 1998). The loss of vegetation has been linked to increased surface albedo, increased dust generation, and reduced productivity of the land (Nicholson, et al. 1998). According to the report of Africa Committee on Sustainable Development under the aegis of United Nations Economic Commission for Africa (UN-ECA Report, 2007), it is estimated that some 60 million will eventually move from the desertified areas of sub-Saharan Africa towards Northern Africa and Europe by the year 2020.

Divergent views about recent rainfall trends over Sahel, with some of recent work suggesting the drought ended during 1990s (Ozer et al. 2003), while others concluded that there was only a partial rainfall recovery (Nicholson, 2005, Lebel and Ali 2009). Recent studies showed a consistent trend for greening in some areas of the region during the last two decades across the Sahel that could be explained by the increasing rainfall and the changes of land use (Olsson et al, 2005). Despite a rainfall recovery in some parts, it is clear that globally the Sahel drought is real and characterized by a greater inter-annual variability (Ali and Lebel, 2009). Predicting how the Sahel rainfall trend will evolve is very uncertain to, according different models for climate projections (IPCC, 2007, Biasutti et al. 2008, Giannini et al. 2008).

Drought in Ethiopia

Historical accounts of famines in Ethiopia go as far back as the 9th century, however, evidence on its impact on health only started to emerge from the 15th century onwards (Taye A, et al 2010). During 1999/2000, great parts of Ethiopia experienced a period of famine which was recognized internationally. The rainfall was high in 1998 but well below average in 1999 and 2000. In 1998, heavy rains continued from April into October, in 1999 the small rains failed and the big rains lasted into the harvesting period. For the years 1998/1999, the mortality rate was 24.5 per 1,000 person-years, compared with 10.2 in the remainder of the period 1997/2001 (Emmelin et al 2008). Mortality peaks reflect epidemics of malaria and diarrheal disease. During these peaks, mortality was significantly higher among the poorer. A serious humanitarian crisis with the Butajira population occurred during 1998/1999, which met the USA-Centre for Disease Control (CDC) guideline crisis definition of more than one death per 10,000 per day.” (Emmelin et al 2008). In extreme droughts such as this one in Ethiopia in 1999/2000, it has been concluded that, the poorest in the farming communities are vulnerable to major health effects as well as economic and social effects. Food insecurity and reliance on subsistence agriculture continue to be major issues in Ethiopia and similar communities. Also, under these circumstances, epidemics of traditional infectious diseases can still be devastating in mal-nourished populations with little access to health care.

Besides substantial economic and social impacts, the health impacts of a severe famine due to drought and/or other causes are hard to measure. However, one survey conducted in 2000 in Gode district of 595 households (4032 people), showed that mortality rate in children under 5 was 6.8/10,000 per day (95% CI 5.4 – 8.2/10,000), which was about double the crude mortality rate of 3.2/10,000 per day (95% CI 2.4 – 3.8) however with 225 (76.8%) of all the deaths having occurred before any intervention had arrived (Salama 2001, Taye et al 2010) The mortality rate was declining by the time intervention was introduced but then it increased, The increase in mortality rate may have been due to influx of non-immune malnourished people to the centralized intervention centers. Almost 80% of all deaths were among children aged 14 years or younger and around 8% occurred among older persons. Wasting, together with one of four major communicable diseases of measles, diarrhoea, malaria and respiratory tract infection, contributed to 206 (70.3%) deaths. The cause of death was different before and after the intervention with:

- 29% versus 15% attributed to wasting alone before intervention
- After intervention respectively, 55% versus 50% attributed to wasting and one of the four major communicable diseases
- 16% versus 35% to one of the four communicable diseases alone.

This indicates that infectious disease had become a more prominent cause of death after the start of intervention ($p < 0.01$ for all) (Salama 2001, Taye A, et al, 2010)

Drought in Syria

Rainfall represents 68.5% of the available water sources in Syria. However due to drought the deficit in available water has been estimated of about 651 million M^3 during the years 1995-2005, and this has increased having an impact on the rainfed agriculture areas, (Nashawatii, 2010). The vegetation cover has been declined in most of areas suffering from drought, (Nashawatii, 2010). It has been determined that for not less than 12 years out of the last 24 years that these drought areas affected by the reduction in rainfall, (Erian 2010).

The drought frequency increased during the agriculture seasons of 2004-2005 to 2009-2010. This forced the local population to immigrate from the northwestern part of Syria and from the Syrian steppe as the winter rainfall was not enough to satisfy cereal crops water requirements and 25% of the animal population in the steppe areas were lost due to the continued drought cycles, (Erian, 2010 and Nashawatii, 2010). During the 2009-2010 growing season, rainfall conditions have been extremely mixed with the most favorable accumulation of rain occurring in western and northwestern regions. Southern, southeastern and northeastern regions all suffered continuing drought conditions and had reduced rainfall, (USDA, 2010). The provinces primarily affected by poor rainfall included the top four wheat producing area which account for 75% of total wheat production in Syria (Al-Hasakah, Ar-Raqqah, Aleppo or Halab, and Dier ez-Zor DATE). Favorable rainfall in April and May is critical to successful growing seasons, and in season 2009-2010 non-irrigated crops were already failing in late March. April rainfall was extremely low throughout northern and northeastern wheat regions this year, causing even greater moisture stress and decimating crop yield potential (USDA, 2010).

Other impacts of drought have included increasing desertification with a greater number of dust storms days (Nashawatii, 2010). Health impacts from dust storm days in Dair El Zohr area in Syria showed that 60% of population, mainly in rural areas, had breathing problems with 70% experiencing eye diseases, 25% suffered digestion problems and emergency cases increasing by 380% .(Al Ebaid, 2000). The toxicity of coarse particles is substantially less than that of fine particles (Al Ebaid, 2000). ,

Drought in South America

Droughts can be due to many climactic events on of which can be the change in weather patterns during an ENSO event (El Niño/La Niña-Southern Oscillation, or ENSO, a climate pattern that occurs across the tropical Pacific Ocean on average every five years). This alters regions of high and low pressures around the globe. This results in high surface pressures that prevent the areas of precipitation from moving into its region and lead to drought conditions, depriving the area and ecosystem of rainfall. Droughts generally occur in the western Pacific during ENSO events, an area normally rich in rainfall. However, droughts in many other regions of the world, including southeastern Africa, India, China and northeastern region of the South American continent, have been linked to El Niño. ENSO results in drier conditions in Northeast Brazil during the Northern Hemisphere winter, the climatic impact of El Niño is drier conditions in Central America, Colombia and Venezuela. During the 1997/1998 El Nino caused severe droughts and forest fires in northeast Brazil. (World Meteorological Organization 1999) The dry spells observed in the La Plata Basin, was studied using daily data supplied by 98 stations during variable periods between 1900 and1998. (Naumann et al 2008) From this it appears that the 1988 drought is considered to be the one of the longest dry spell in the basin. Water deficits translate to Argentinean economic losses of more than four billion dollars.

In 2005 large sections of southwestern Amazonia experienced one of the most intense droughts of the last hundred years. (Marengo et al 2007) The drought severely affected human population along the main channel of the Amazon River and its western and southwestern tributaries, the Solimões (also known as the Amazon River in the other Amazon countries) and the Madeira River, respectively. The river levels fell to historic low levels and navigation along these rivers had to be suspended. The causes of the drought were not related to El Niño but to: 1) the anomalously warm tropical North Atlantic, 2) the reduced intensity in the northeast trade wind moisture transport into southern Amazonia during the peck summertime season, and 3) the weakened upward motion over this section of Amazonia, resulting in reduced convective development and rainfall. The drought conditions were intensified during the dry season into September 2005 when humidity was lower than normal and air temperature were 3º - 5º warmer than normal. Because of the extended dry season in the region, forest fires affected part of south western Amazonia. Rains returned in October 2005 and generated flooding from February 2006.

One of the worst droughts in 50 years occurred in 2008 and 2009, which devastated crops, dry rivers and springs, and killed cattle in Argentina, a phenomenon also impacted on socio-economic and productive communities and regions. La Niña 2008-2009 depleted water reserves not only in Argentina but also in Paraguay, Uruguay and Brazil. According to the Meteorological Weather Service of Argentina (SMN), during 2008 observed rainfall values were below normal in most of the humid and semi-humid region of the country (the Pampas), comparing with the main value of the period 1961-1990. The accumulated rainfall in the center of the region represented only 40-60% of the normal values, and in some locations values of precipitation were the lowest of the last 47 years.

Drought Effects

Few extreme events are as economically and ecologically disruptive as drought, which affects millions of people in the world each year (Wilhite 2000). Severe drought conditions can profoundly impact agriculture, water resources, tourism, ecosystems, and basic human welfare (see also chapter 3 for a discussion of these aspects). Over the United States, drought causes $6–8 billion per year in damages on average, but as much as $40 billion in 1988, Federal Emergency Management Agency (FEMA 1995). EM/DAT data showed that about 2.63 million people were affected by hydro-metrological disasters globally during 1997-2006 with about 41.82% are affected by drought, and 38.87% of them were affected during 2002 (World Disaster Report 2007),. During 1997-2006, hydro-metrological disasters caused an estimated damage of US$ 66.8 billion per year on average out of this 4.62% caused by drought. Average number of people reported killed by drought in million per year are, Asia (81.11), Africa (26.69), Americas (2.57), Europe (0.14). The impacts of drought are likely to become ever more severe as a result of development processes and population increases (Squires 2001). Droughts often stimulate sequences of actions and reactions leading to long-term land degradation, (Erian 2010).

Dust storms are related to drought, precipitation, soil moisture, beside other factors such as land use and land cover practices, and other human activities. A lack of precipitation often triggers agricultural and hydrological droughts, but other factors, including more intense but less frequent precipitation, poor water management, and erosion, can also cause or enhance these droughts. For example, overgrazing led to elevated erosion and dust storms that amplified the Dust Bowl drought of the 1930s over the Great Plains in North America, (Cook et al 2009). Dust storms have increased in the Mediterranean and East Asia regions over the last decade These storms can travel over large parts of Asia, Africa, even affecting North America and Europe, (McKendry et al.2001). The Sahara is the largest source of desert dust, indicating the importance of aeolian geomorphology in this major world desert, (Middleton and Goudie 2001).

Dust storms may be linked to lethal epidemics. A gram of desert soil may contain as many as 1 billion bacterial cells, the presence of airborne dust should correspond with increased concentrations of airborne microorganisms, (Griffin 2006) dust storms resulted in the greatest mass of Asian dust transported to North America in at least the past 20 years and contributed significantly to surface PM levels across the U.S, (Zhao etal., 2007).

Dust storms are also playing an important role in the supply of nutrients and micronutrients to the oceans and to terrestrial ecosystems, (Shinn et al 2000, and Sivakumar 2005). Mineral dust is a term used to indicate atmospheric aerosols originated from the suspension of minerals constituting the soil, being composed of various oxides and carbonates. Human activities lead to 30% of the dust load in the atmosphere. The Sahara is the major source of mineral dust, which subsequently spreads across the Mediterranean and Caribbean seas into northern South America, Central America, North America, and Europe. Additionally, it plays a significant role in the nutrient inflow to the Amazon rainforest, (Koren et al 2006). The soil of the Amazon tropical rainforest is shallow, poor in nutrients and almost without soluble minerals. Heavy rains have washed away the nutrients in the soil obtained from weathered rocks. The rainforest has a short nutrient cycle, and due to the heavy washout, a stable supply of minerals is required to keep the delicate nutrient balance, (Vitousek and Stanford, 1986).

About 40 million tons of dust are transported annually from the Sahara to the Amazon basin, Saharan dust has been proposed to be the main mineral source that fertilizes the Amazon basin, generating a dependence of the health and productivity of the rain forest on dust supply from the Sahara, about half of the annual dust supply to the Amazon basin is emitted from a single source: the Bodélé depression located northeast of Lake Chad, approximately 0.5% of the size of the Amazon or 0.2% of the Sahara. Placed in a narrow path between two mountain chains that direct and accelerate the surface winds over the depression, the Bodélé emits dust on 40% of the winter days, averaging more than 0.7 million tons of dust per day (Koren et al 2006). Central and South American rain forests get most of their mineral nutrients from the Sahara; Traces of African dust have been discovered as far west as New Mexico. According to Swap (1992). The western states are also the recipients of dust that's been stirred up in China's deserts and blown across the Pacific; the area of dust cloud observed was 1.34 million Km2, the mean particle radius of the dust was 1.44 mm, and the mean optical depth at 11mm was 0.79, the mean burden of dust was approximately 4.8 tons/Km2 and main portion of the dust storm on April 07,2001 contained 6.5 million tons of dust, (Yingxin et al, 2003).

Drought Management

The traditional approach to drought management has been reactive, relying largely on crisis management. This approach has been ineffective because response is untimely, poorly coordinated, and poorly targeted to drought stricken groups or areas, (Wilhite 2005). White added that two important trends in drought management could be considered: (1) improved drought monitoring tools and early warning systems EWSs and (2) an increased emphasis on drought preparedness and mitigation. The Arab Center for The Studies of Arid Zones and Dry Lands (ACSAD), headquarter in Syria works closely with the ministry of Agriculture in Syria, Jordon, Lebanon and Egypt for empowering their drought monitoring unit and develop drought strategy at the meantime other activities are ongoing for improving the productivity of rainfed areas which focus on reducing the adverse effects of drought have been underway for at least 2-3 decades. The tool box of ACSAD to deal with drought and Arid areas within Arab region includes activities such: water harvesting, supplementary irrigation, rehabilitating depredated areas, Conservation agriculture, Integrated Water Management System, Use of non-traditional Water and Increase Irrigation Efficiency, prepare potential Land Use Mapping, introduce conservation agriculture, adding manure to soil to improve its holding condition, recycled organic solid waste from farm residuals and add to soils, Follow crop rotation, produce new breeding cereal seeds tolerant to stresses such as drought, heat , salinity and diseases, Improve Small Cartel Productivity and give more capacity building, (ACSAD 2009, ACSAD/ GTZ 2010).

Lessons Identified

- Already water resources are stressed in some areas around the world and therefore highly vulnerable, especially with respect to competition for water supply between agriculture, power generation, urban areas, and environmental flows (high confidence) and salinization. Increased evaporation and possible decreases in rainfall in many areas would adversely affect water supply, agriculture, and the survival and reproduction of key species in parts of the world that depend on uncertain sources.
- Political issues play a role within drought risk management. Investment and promotion of inter-disciplinary dialogue to improve awareness and to define the issue and communication to address drought risk would be elements of effective response and such strategies are important. For those governments where there are risks of drought, they might wish to consider investing effort to develop these strategies and dialogues.
- Drought needs a cross-cutting approach and therefore requires a wide range of inputs (e.g. cultural, socio-economic, etc.). Accordingly drought management capacities could be strengthened, including capacities to develop integrated plans, if appropriate. Evaluation of risk management measures and practices could also be undertaken to determine if they are effective.
- The health impact of drought is complex and can cause long standing issues affecting health and livelihoods of successive generations. Robust surveillance systems to record impact on health and to inform action could contribute to understanding that impacts are reduced effectively.
- Drought has an impact on socio-economic stability particularly with migration from rural areas with water shortages and food scarcities.

- Better agreement on triggers for early warning and actions to improve preparedness within particularly vulnerable areas by changing land use and crop patterns, introducing new seed varieties more tolerant for drought, improve community socio-economical preparedness (assets, governance and technology) and create alternative economic opportunities.

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Case Study 9.2.4. Floods Managing Complex Interactions between Hydro-Meteorological and Hydro-Geological Processes

Floods are a major natural hazard in many regions of the world (Ahern et al 2005). According to the data of Munich Reinsurance Company, about half of all fatalities connected to natural disasters and 30% of the economic losses are caused by floods (Munich Re, 2001). Vulnerability and exposure are key determinants of disaster risk.

Catastrophic Floods in Mozambique – Lessons and Actions

Mozambique is very vulnerable to natural disasters especially floods because of climatic factors and geographical position. Nine out of the eleven rivers in Mozambique are trans-boundary rivers. Mozambique is the last riparian country before the rivers discharge into the Indian Ocean. Therefore the development and function of early warning and flood control systems for Mozambique need to be based on a close collaboration with other countries of the Southern Africa Development Community (SADC).

Floods in 2000: Event Summary and Impacts on the Population and Economy

Natural disasters are one of the main risks to the achievement of Mozambique's poverty reduction strategy. From 1965 to 1998, there were twelve major floods, nine major droughts and four major cyclone disasters (World Bank, 2005). One of the most destructive floods has occurred in the winter 2000 when the coast of Mozambique has been attacked by a series of tropical cyclones that has led to extensive flooding (Van Biljon, 2000). Floods affected 12.1% of the population in five provinces and 699 lives were lost. About 90 % of the irrigation structure in the affected areas was damaged. On the estimation of the World Bank the direct losses amount to US $273 million, and the lost production amounts to $247 million (UN General Assembly, 2000).

The epidemiological study during the floods in the most affected area in the mid south of Mozambique detected the infectious diseases in 85% of all of patients, predominantly malaria, respiratory infectious diseases, and diarrhea (Kondo et al 2002). Malaria had increased by four to five times over non-disaster periods with both the incidence and the risk of infection augmented following the flood. The increase in infectious disease incidence was connected to the heightening of the associated risk factors: increase of population density; worsening temporary living conditions; the degeneration of quality of drinking water; and the deterioration of physical strength due to lack of food.

Role of Key Personnel and Agencies

One of the major problems for authorities is timely pre-warning of people about the potential occurrence of a natural disaster. It allows not only the opportunity to reduce material losses, but, in a number of cases, to save human lives (Environment Agency 2010). Success and effectiveness of warnings depend not only on accuracy of the forecast, but also their delivery in adequate time before the disaster to put in place prevention strategies. In addition it is very important that a warning has been received by each person in the disaster zone. The warnings should be understandable for people without special training. In 2000 most people in the affected areas received warnings issued by the water management about the rising river levels and warned people in low-lying areas to move to higher ground. However, the warnings were qualitative in nature, and they failed to convey the magnitude of the event (Kwabena et al. 2007). This scenario has great implications for understanding the communication systems and their role in facilitating CCA, as it is through good communication that knowledge transfer and innovation can enhance early warning systems. Poor communication flow can impede the awareness of risk determinants diminishing the ability to adapt to climate change.

Lessons and Action after Floods 2000

The important problem is the sustainability of the monitoring and forecasting system. In 2000 in Mozambique there were problems with the installation and maintenance of in situ gauging equipment due to financial constraints. In addition, the hydrological and precipitation gauges are often washed away and many key stations were destroyed, leaving Mozambican water authorities with no source of information on the actual magnitude of floodwater (Asante et al. 2005). The enormous material damage and human losses during the floods in Mozambique in 2000 were associated with the following problems:

- *Institutional problems*. In 1999 National Policy on Disaster Management in Mozambique only began to shift from a reactive to a proactive approach in disaster management aimed at developing a culture of prevention (World Bank 2005)
- *Technological problems*. Before the floods of 2000 active observational hydro-meteorological measurement in Mozambique had been rare. There were no reliable methods for quantitative forecasting of the hydrograph for the river of Mozambique. To ensure the secure, reliable and timely hydrological information during the start and development of flood requires close cooperation with all countries situated within trans-boundary river basins.
- *Financial problems*. Insufficient budgetary resources singled out for the creation, development and maintenance of the National Policy on Disaster Management.

Mozambique's government learned some lessons from the devastating floods that hit the country in 2000. In 2001, the government of Mozambique adopted an Action Plan for the Reduction of Absolute Poverty (PARPA I), which was revised for the period 2006–2009 (PARPA II) (Foley 2007, The National Action Plan for the Reduction of Absolute Poverty 2001, Republic of Mozambique Action Plan 2006). In 2006 the government adopted a Master Plan, which provides a comprehensive strategy for dealing with Mozambique's vulnerability to natural disasters. After the floods 2000 Mozambique implemented intensive programs to move people to safe areas. Thus over the past five years about 120,000 families have been resettled. The country has put in place early warning systems some of which are operated by community members. An example of this is the Búzi Early Warning System. For the development of modern preparedness strategies and early warning systems on the international level the South African Weather Service has developed a proposal to set up a regional flash flood warning system that would cover all affected countries within the region which Mozambique will be part of.

Event Summary of Floods 2007

Seven years after the catastrophic floods in 2000 a similar situation with floods in Mozambique was repeated, but the country was ready for these dangers in a greater extent than before. Between December 2006 and February 2007, strong rains across northern and the central Mozambique together with a serious downpour in neighboring countries, have led to flooding in the Zambezi River basin (DREF Bulletin, 2007). Additional flooding has been linked with the approach of tropical cyclone Favio which struck the Búzi area at the end of February 2007. During flood period in the southern coast of Mozambique, nine people were killed, 70 people were injured. The heavy rains and floods damaged health centers, Public and administrative buildings, drug stocks and medical equipment and affected safe water and sanitation facilities (UN OCHA 2007). In total, the floods and cyclone caused approximately $71 million in damage to local infrastructure and destroyed 277,000 hectares of crops primarily in Inhambane Province (U.S. Agency for International Development Bureau for Democracy 2007). The total number of people affected during the floods in January-February 2007 in Mozambique is estimated to have been between 300,000 and 500,000. On data of the World Food Program (WFP) the floods affected 285,000 people and the cyclone 150,000 more (WFP Mozambique, 2007). USAID estimated that 331,500 people had been affected by the flood and 162,770 by the cyclone (USAID Mozambique 2007).

Activities of Local Authorities and International Organizations before and during Floods

After flooding 2000 authorities and agencies of Mozambique together with foreign partners have executed great activities on preparation for acts of natural disasters. In 2005- 2006 the German Agency for Technical Cooperation (GTZ) developed a simple but effective early-warning system along the River Buzi (Loster et al. 2007). This warning system was adapted to the specific needs and skills of the people. The village officials receive daily precipitation and water level at strategic points along the Buzi river basin. If precipitation is particularly heavy or the river reaches critical levels, this information is passed on by radio and blue, yellow or red flags are raised depending on the flood-alert level. This is a good example of a scientific high technology adaptation for DRM that has been tailored to the local community and capability.

To prevent outbreaks of infectious diseases the U.N. Children's Fund (UNICEF) and the International Federation of Red Cross and Red Crescent Societies (IFRC) raised public awareness through health campaigns. To address the increased risk of vector-borne diseases USAID/OFDA provided financial means for the procurement and transportation insecticide-treated mosquito nets to flood-affected populations. To mitigate the spread of disease, the U.N. Population Fund, in coordination with the GRM's Ministry of Health, has distributed hygiene kits in accommodation centers. These are all good examples of international cooperation for health protection. To address emergency food needs, UNICEF and WFT provided food assistance to people in affected zones. In response to previous and recurrent flooding in Mozambique, the INGC has established accommodation and resettlement centers to provide temporary shelter to flood-affected families. To meet the basic needs of displaced populations, IFRC are distributing emergency relief supplies to more than 23,000 families.

Lessons Identified from Other Flood Events

South Korea: Impact Determined by Previous State of the Environment

The impact of an extreme event can be greatly determined by the prevailing condition of the environment. Since the late 1990s Gangwon Province in South Korea has experienced several severe wildfires as a result of droughts as in 1996, 2000 and 2005 (NEMA, 2009; 2004). These resulted in deforestation, especially on the steep mountainsides. Therefore, those areas were left with a high potential for landslide risk in case of heavy rainfalls.

In 2006, Typhoon Ewiniar struck Korea. As the typhoon filled and weakened, heavy and persistent rainfall continued in the mountainous northeastern part of the country, especially in Gangwon Province, with 82mm of hourly rainfall at Pyeongchang County (Gangwon Province, 2007). The rainfall led to severe landslides, which brought a great amount of debris into streams, and consequently significant flooding. In contrast, other neighboring areas with similarly intense precipitation suffered from much less secondary mass movement or consequential flooding, because they had not had the previous degradation of the landscape or were better prepared after experiencing severe typhoons such as Rusa in 2002 and Maemi in 2003 (NEMA, 2007).
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Since the damaged areas were not highly populated, nor farmed, the total damage was not high enough for the event to be classified as a major disaster. However, damages to the natural ecosystem and to infrastructure were very severe: rivers, hill slopes, and roads were devastated, and the rural population lost its means of livelihood. The Korean government declared the affected region a major disaster area, thereby facilitating financial assistance. After this compound disaster, the government and the local people worked diligently toward recovery of the damaged areas, and started a program to control soil erosion and to build dams in potential risk areas to prevent debris from flowing downstream (Gangwon Province, 2007).

Russia Republic of North Ossetia

The accumulation of the effects of many small disasters may be as damaging or worse than one large disaster.

In September 2002, a huge natural catastrophe destroyed the Genaldon valley in the Russian Republic of North Ossetia. Enormous masses of ice mixed with water and stone broke loose and rushed down the valley with high velocity, devastating everything along the way and stripping the slopes of forest and loose sediments up to a height of over 100 m. The avalanche was stopped by the Skalistyi mountain range, which runs perpendicular to the valley, but glacial debris flow burst through and brought ruin for the next 17 km.

The formed rock/ice avalanche had a volume of about 100.106 m^3 and travelled down the Genaldon valley for 20 km. A mudflow, however, continued moving for another 15 km and stopped in 4 km before reaching the town of Gisel. The avalanche and the mudflow caused the death of about 140 people and destroyed important traffic routes, residential buildings and other infrastructures. The ice/debris deposits formed several marginal lakes of up to 5,000,000,000 m^3 of water. Potential floods from these lakes were an imminent threat to the downstream areas

(Kaab, 2003a; Haeberli et al., 2005). The village of Nizhnii Karmadon and several rest homes along the Genaldon River below the gorge were completely destroyed.

According to investigations of some scientists the premature surge of the glacier and huge scale of the catastrophe were provoked by complex of factors such as:

- Accumulation of great quantities of water in and under the glacier, due to special climatic and meteorological conditions;
- Volcanic activity; this caused additional melting of the bottom of the glacier;
- In addition, ice and rock falls overloaded the rear part of the glacier and increased the tension in its body.
- Tectonic structure of the region: the Kolka valley is situated in a zone of large sub-latitudinal faults where displacements of individual blocks and earthquakes are highly probable.
- A direct trigger for the glacier surge might have been just another minor fall, a small earthquake, or simply a destructive process inside the glacier that created a critical tension in its body. (Kotlyakov V.M., 2004; Huggell C., 2005).

England to Wales: The Impact of Heavy Rainfall

In England and Wales the rainfall during June and July 2007 was unprecedented (Pitt Review 2008). The severe flooding which followed came after the wettest ever May to July period since national records began in 1766. The UK Meterological Office records show that the total cumulative rainfall in May, June and July 2007 averaged 395.1mm across England and Wales – well over double usual levels. This exceptionally heavy rain resulted in two severe and disruptive flooding events; the first during the week of 20 June and the second during the week of 18 July. A clear indication of where the heavy rain fell can be seen in the maps of precipitation levels for England and Wales during 24–25 June and 19–20 July 2007 (Figure 9-1).

[INSERT FIGURE 9-1 HERE:
Figure 9-1: Precipitation levels for England and Wales during 24-25 June and 19-20 July 2007.]

The consequences of the rain was severe flooding with approximately 55,000 properties flooded, around 7,000 people were rescued from the flood waters by the emergency services, adverse health effects were reported and 13 people died. In Yorkshire and Humberside approximately 48,000 households and nearly 7,300 businesses were flooded causing billions of pounds worth of damage. In Gloucestershire, the Mythe Water treatment works was flooded and left 350,000 people without any mains water supply, and the hospitals were also greatly affected (Whitely 2007).

The UK also had the largest loss of essential services since World War II, with almost half a million people without mains water or electricity. Even telecommunications were disrupted. Transport networks failed, a dam breach was narrowly averted and emergency facilities were put out of action. When the Pitt Public Enquiry sat in 2008 they were told that the insurance industry expected to pay out over £3 billion with other substantial costs being met by central government, local public bodies, businesses and private individuals (Environment Agency 2010).

This public enquiry recommended four main areas to improve response

- Improve the quality of flood warnings (Environment Agency 2009)
- Improve flood risk management to protect communities through robust building and planning controls
- Improve protection within critical infrastructure to avoid the loss of essential services such as water and power and for all sectors to be more open about risk
- Improve UK knowledge by learning from good experience abroad and in particular better advice on how to protect their families and homes; raise the awareness through education and publicity programmes; learn more on how people can stay healthy to speed up the whole process of recovery

Conclusion

Floods show that the efficient managing of the risks of extreme events and disasters is vital to advance climate change adaptation. Studying cases of extreme natural phenomena with the purpose of creating reliable systems of monitoring, forecasting and informing of the population on threat of natural accidents and reactions to these threats for the prevention or mitigations of negative consequences including health impacts is hugely important (Caldin and Murray 2011). In particular:

- Long-term adaptation to extremes of climate and associated hydrologic extremes requires understanding and are important. Governments may wish to consider investing effort in developing strategies for climate smart Disaster Risk Management (EEA 2010).
- The importance of adapting disaster risk management to new climate change situations becomes very apparent when disasters cross international boundaries (WHO Europe 2010).
- Risk perception and awareness, adaptation and risk reduction effectiveness depend on appropriate risk communication (Whittle et al 2010).
- Natural disasters not only cause financial losses and casualties, but also cause people to think about how to prevent or reduce losses from disasters in future. Formulation of a reasonable strategy of the disaster risks management in the conditions of increasing threats of extreme natural disasters is one of the main tasks of adaptation to climate change (Cosford 2009).

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Case Study 9.2.5. Complex Disasters Induced by Hot Weather - Victoria, Australia: Reducing Wildfire Suppression Costs and Ecological Disasters

<u>Introduction</u>

Climate change is expected to increase global temperature and changing rainfall patterns. These climatic changes are likely to increase the risk of extreme weather induced disasters such as droughts, heat waves and wildfires. The effects may vary by sub-regions and localities, but in general the following may be expected to take place: (i) increase in temperature and decrease in mean precipitation leads to an increase in the frequency and severity of drought and heat waves; (ii) Severe drought and heat waves leads to an increase in wildfires; and (iii) severe wildfire causes severe floods and landslides in case of greater intensity of rain. The goals of this case are to present weather-related hazards, their effects and potential impacts and provide an overview of measures to mitigate and manage these risks.

Effects of Extreme Weather-Induced Disasters

With climate change, hot dry conditions are very likely to become more frequent. Central Australia has warmed 1.5 – 2.0 °C over the last century (State Government of Victoria 2009). Over the last 12 years from 1998 to 2009, Victoria has experienced warmer than average temperatures and experienced a decline in average rainfall of 14 % (DSE 2008). Victoria has been the warmest on record, breaking records going back 154 years over the last decade (State Government of Victoria 2009; Parliament of Victoria 2009). In central Victoria the 12-year rainfall totals have been around 10 to 20% below the 1961 – 1990 average and 10 to 13% below the lowest on record for any 12-year period prior to 1997 (State Government of Victoria 2009). Across Victoria the average annual rainfall during this drought has been 555mm, compared with a long-term average (1961 – 1990) of 653mm (Australian Government 2009).

The number of dry spells and the risk of drought are likely to increase in SEM, notably in southern Europe (Lehner et al. 2006). Annual temperatures are projected to increase in SEM and the Mediterranean more than the global average (IPCC 2007; Moreno et al. 2010). Maximum temperatures are also likely to increase more than average or minimum temperatures (IPCC 2007; Moreno et al. 2010). Annual precipitation is very likely to decrease in most of SEM, and the number of wet days is very likely to decrease. Globally droughts are the second most geographically extensive hazard after floods i.e., covering 7.5% and 11% of the global land area each. The combination of a decrease in rainfall and increased evaporation will lead to more severe and longer-lasting droughts and heat waves in some areas. Australia is the driest inhabited continent even though some areas have annual rainfall of over 1200mm. The average elevation of Australia is less than 300m, compared with the world's mean of about 700m. This low elevation, coupled with the latitudinal position extending from 10°41'S in the north to $43^0$39'S in the south, contributes to the general aridity of Australia. More than one-fifth of its land area is desert, more than two-thirds being classified as arid or semi-arid, unsuitable for settlement.

The impacts of an extreme event can be greatly determined by the prevailing condition of the environment. Wildfire behavior is modified by climate, forest management, and fire suppression (Allen et al., 2002; Noss et al., 2006), and understanding the reasons for changing wildfires is further complicated by changes in fire reporting over the period of record. The maximum temperature will very likely increase the frequency of extreme fire danger conditions and with it the probability of fire, particularly of large fires (Vázquez and Moreno 1993; Piñol et al. 1998; Viegas 1998; Pausas 2004; Trigo et al. 2006; Australian Government 2009). However, recent changes in climate were likely the main drivers for increases in area burned in the western United States (Westerling et al., 2006), Canada (Gillett et al., 2004; Kasischke and Turetsky, 2006; Girardin, 2007) and Australia (Australian Government 2009).

Impacts of Extreme Weather-Induced Disasters

The impacts of an extreme weather induced disasters can be greatly determined by the prevailing condition of the environment. Hotter temperatures and lower rainfalls lead to dryer forests resulting in larger and more serious fires. As a leading case to illustrate the impacts of extreme weather induced disaster, the Victoria bushfires, 7 February 2009 well demonstrate the inter-relationship among the extreme weather induced disasters such as droughts, heat waves and wildfires. And then fire examples both in Europe and Republic of Korea follows to illustrate their effects and potential impacts.

Droughts in Melbourne

The day of the fires came after 12years of the state's hottest and longest drought (Trewin and Vermont, 2010). Over this period, the whole of south-east Australia suffered a severe and protracted drought which is without historical precedent. Rainfall deciles for January and February 2009 indicate that both months are very much below average

(Australian Government 2009). The 2009 winter season in Australia brought below normal precipitation across much of the country. A large portion of southern Victoria, notably the area that surrounds Melbourne, received the lowest rainfall on record. The same has been experienced in western Victoria (State Government of Victoria 2009). Decreased water supply along with warmer temperatures is likely to increase drought risk and severity (CSIRO, 2007). The most significant and inherent risk in drought is insufficient water supply for Victoria. Not only droughts will very likely increase the extreme fire danger conditions but also severe wildfire causes severe drought by contamination of drinking water by ash and debris inflow into reservoirs in the burned catchments. Forested catchment areas supplying five of Victoria's nine major dams were affected by the fires, with the worst affected being Maroondah Reservoir and O'Shannassy Reservoir. As of 17 February, over ten billion litres of water had been shifted out of affected dams into others.

Heat Waves in Victoria

The heat waves began in South Australia on 25 January but became more widespread over southeast Australia by 27 January 2009. The temperature was above 43°C for three consecutive days from 28–30 January reaching a peak of 45.1°C on 30 January 2009 which temperature was the second-highest on record behind 45.6°C on 13 January 1939. Overnight temperatures were also extremely high with Melbourne Airport's minimum of 30.5°C on the 29 January only 0.4°C short of the Victorian record. The extremely high day and night temperatures combined to make a record high daily mean temperature of 35.4°C on 30 January (State Government of Victoria 2009). The exceptional heat wave was caused by a slow moving high-pressure system that settled over the Tasman Sea, with a combination of an intense tropical low located off the North West Australian coast and a monsoon trough over Northern Australia, which produced ideal conditions for hot tropical air to be directed down over Southeastern Australia (National Climate Centre 2009).

The heat wave has clearly had a substantial impact on the health of Victorians, particularly the Elderly (National Climate Centre 2009; Parliament of Victoria 2009). For the week of the heat wave from 26 January to 1 February 2009, 25% increase in total emergency cases and a 46% increase over the three hottest days. Emergency Department report that 12% overall increase in presentations, with a greater proportion of acutely ill patients and a 37% increase in those 75 years or older (State Government of Victoria 2009; Parliament of Victoria 2009). Mortality during heat waves can be difficult to measure, as deaths tend to occur from exacerbations of chronic medical conditions as well as direct heat related illness, particularly in the frail and elderly. However, excess mortality provides a measure of impact of heat waves. For the total all-cause mortality, there were 374 excess deaths which a 62% increase in total all-cause mortality. The total number of deaths was 980, compared to a mean of 606 for the previous 5 years. Reportable deaths in those 65 years and older were more than doubled for the same period in 2008 (State Government of Victoria 2009; Parliament of Victoria 2009).

Victoria's Bushfire

The intensity and speed a bushfire travels depends on amount and arrangement of the fine dead fuel, moisture content of the dead fuel, wind speed near the flaming zone and terrain and slope. Fire danger is the sum of all factors that affect the inception, spread, and difficulty of control of fires, and the damage they cause. The total concept of fire danger is impossible to embody in a single, practical index. However, the McArthur Forest Fire Danger Index (FDI) is based around providing a relative measure of the difficulty of suppression for a standard fuel type. The FDI reached unprecedented levels, ranging from 120 to over 200 around 7 February 2009. This was higher than the fire weather conditions experienced on Black Friday in 1939 and Ash Wednesday in 1983 (Bureau of Meteorology 2009). Over this period, temperatures were being reached, 46.4 °C in Melbourne, humidity levels dropped to as low as 6% and rainfall deciles for January 2009 are very much below average. By midday, wind speeds were reaching their peak of 120 km/h and power lines were felled in Kilmore East by the high winds, sparking a bushfire that would later generate extensive pyrocumulus cloud and become the largest, deadliest and most intense firestorm ever experienced in Australia's post-European history. The overwhelming majority of fire activity occurred between midday and 7 pm, when wind speed and temperature were at their highest and humidity at its lowest.

A total of 173 people were confirmed to have died and total of 414 people were injured as a result of the Black Saturday bushfires (Australian Government 2009). Of the people who presented to medical treatment centers and hospitals, there were 22 with serious burns and 390 with minor burns and other bushfire-related injuries. The fires destroyed over 2,030 houses, more than 3,500 structures in total and damaged thousands more. The fires destroyed almost 430,000 hectares of forests, crops and pasture, more than 2,000 properties and over 55 businesses (Australian Government 2009). Three primary schools and three children's services were destroyed with 47 primary schools partially damaged or requiring cleaning.

Wild Fires in Europe and Asia

Every year, approximately 50.000 fires are recorded in Europe, mainly in SEM, where they burn 0.5 MHa (San Miguel and Camia 2009). Despite similar or even more dangerous climatic conditions in the countries of the southern rim of the Mediterranean Sea, or in part of the Anatolian Peninsula, fires in these areas are fewer (Dimitrakopoulos and Mitsopoulos 2006), although Turkey suffered the largest fire in their historical records in 2008, amounting some 20,000 ha. By the late 1960's wildfires started to occur at an increasing rate in all countries of the European Community (Alexandrian and Esnaut 1998). Area burned increased during the 1970's and into the 1980's, by which time Spain and Italy had reached maximum values (Moreno et al., 2010). Greece and Portugal followed suit with some delay. During this decade of transition none of the northern African countries or Turkey experienced a similar increase.

Fires became more frequent during the second half of the 20th century, but also more widespread. In general, the number of large fires seems stable (San Miguel and Camia 2009), in some areas is increasing (González and Pukkala 2007). In Bulgaria, the warm and dry conditions led to 1,400 wildfires that consumed more than 58,000 hectares, destroying 73 homes. Greece also suffered from hundreds of fires during the height of the heat wave, particularly on Samos, where fire consumed one-fifth of the island. In Russia in 2010, a similar complex heat event occurred as in Victoria in 2009 with drought and forest fire, which the smoke resulting in air pollution causing adverse health impacts. Fire occurrence may be linked to not only particular abiotic or human factors but also land-use and land-cover experienced. Fires do not burn at random the vegetation (Nunes et al. 2005) and also have preference for certain topographic locations, or distances to towns or roads (Mouillot et al. 2003; Badia-Perpinyà and Pallares-Barbera 2006; Syphard et al. 2009).

In the case of the Greek fires in 2007, the risk of causalities and of direct damage to homes and infrastructures is very high in these areas of that natural vegetation is invading the old fields and getting close to the houses (Tolika et al. 2007). In Spain, the types of vegetation burned have been changing, from more wooded dominated areas to shrub-land dominated areas (Pausas and Verdú 2005; Pausas et al. 2006). This fact, in combination with other long-term anthropogenic disturbances, may cause further fire-induced degradation beyond the resilience domain of Mediterranean ecosystems. As a consequence of this long-term human impact, most of the Mediterranean basin is now regarded as 'degraded' (TNC 2004).

Post-fire vegetation recovery is also important in itself but also because it is a major factor controlling post-fire erosion and flash flood risk (Vallejo and Alloza, 1998). High soil erosion rates are irreversible at the ecological time scale; therefore, it is a major potential impact of wildfires. In the case of the Republic of Korea in 2000, the dry and windy climate caused by foehn winds during spring, and high-density planting on steep slopes which is likely to increase risk of wildfires can accelerate flame propagation over a wide area. Over nine days, 23,448 ha of forest area rapidly burned due to propagation under heavy winds, with a maximum instantaneous wind speed of 25 m/s (Kim et al. 2008). These damages, especially on the steep mountainsides led to severe landslides, which brought a great amount of debris into stream, reduced flow capacity and even blocked the channel before the channel structures especially small bridges, and consequently significant flooding in case of greater intensity of rain, most notably from Typhoon RUSA in 2002.

Management of Extreme Weather-Induced Disasters

The key adaptation measures for Melbourne's drought are considered to provide benefits across drought risks, this is storm water harvesting. This can assist in both flash flooding events and with insufficient water supply. Melbourne has 10 major reservoirs and they store and hold up to 1,810,500 million liters of water. As storm water volume in Melbourne is almost equal to potable water consumption, this is a valuable resource. The water restriction regime of Melbourne has helped manage the significant drought issues of recent years. Another key focus fire season is protecting the Upper Yarra and Thomson catchments, which hold the majority of Melbourne's water supply and were largely untouched by Black Saturday. In order to prevent contamination of Melbourne's drinking water by ash and debris, Melbourne Water has moved water out of fire-affected catchment areas to other catchments.

The Victorian Government identified the need to respond to predicted heat events in the Sustainability Action Statement released in 2006 which committed to a Victorian Heat Wave Plan involving communities and local government. As a part of this strategy the department has established a heat alert system for metropolitan Melbourne and is undertaking similar work for regional Victoria. They are also trying to develop a toolkit to assist local councils in the preparation of heat wave response that could be integrated with existing local government public health and/or emergency management plans.

Prior to 7 February the State Government devoted unprecedented efforts and resources to informing the community about the fire risks Victoria faced. That campaign clearly had benefits, but it could not, on its own, translate levels of awareness and preparedness into universal action that minimized risk on the day of the fires. This is a shared responsibility between government and the people. However, there were a number of weaknesses and failures with Victoria's information and warning systems on 7 February. Relying on local knowledge, in combination with fire managers' decision-making abilities, could improve fire management options and reduce wildfire suppression costs and ecological disasters (Kalabokidis et al. 2008).

Recovering ecosystem resilience in those abandoned lands would thus require breaking degradation loops and promoting secondary succession towards more mature, more resilient plant communities (Vallejo and Alloza 1998). Given the threats of changes in fire and other climate and global changes over the values at hand, not the least its distinct and rich biodiversity, the challenge of conserving these territories under the ongoing climate and land-use/land cover changes and other global changes is paramount (Fischlin et al. 2007). The Victorian government intends to debate new fire related planning and building code standards. In response to the Victorian bushfires new building regulations for bushfire-prone areas have been fast tracked by Standards Australia (Bustos 2009). The Korea government started program for stream design criteria to cope with changes in fire and other climate and to build debris barrier in potential risk areas to prevent debris from flowing down stream.

Lessons Identified

By 2030, average annual temperatures are expected to rise by 0.6 to 1.1°C with slightly more warming in summer and less warming in winter and the average stream flow is likely to drop 3 - 11% by 2020 and 7 - 35% by 2050 in Melbourne (CSIRO 2007). The most significant extreme events for Melbourne likely to be exacerbated by these climate changes are drought, heat waves and wildfires. There are also increasing public health issue driven by increasing numbers of vulnerable elderly and the increasing heat island effect resulting from progressive urbanization in Melbourne (State Government of Victoria 2009).

A key adaptation measure for Melbourne to lessen the impact of drought could include storm water harvesting, the volume of which is considered to be almost equal to potable water consumption. Investment and development of multiple reservoirs operating a shared program to define the issue and communication to move water out of fire-affected catchment areas to other catchments would possibly prevent contamination of Melbourne's drinking water by ash and debris.

Strengthening risk management capacities including (i) prior campaign for awareness, (ii) information and warning systems, (iii) translation levels of awareness and preparedness into universal action, (iv) sharing responsibility between government and the people and (v) enhancing managers' decision-making abilities to develop integrated plans could be part of future strategies.

High soil erosion rates in burned area are irreversible at the ecological time scale; therefore, it is a major potential impact of flood and wildfires. Political issues as well play a great role within the wildfire risk management and should be committed to create extreme event related plan and building codes for recovering ecosystem resilience in those abandoned lands to break degradation loops and promote secondary succession towards more mature, more resilient plant communities. In order to prevent severe flood damages in burned area, effective risk management such as stream design criteria to cope with changes in fire and other climate and to build debris barrier to prevent debris should keep in focus.

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Case Study 9.2.6. Complex Cold Climate Impacts - The Arctic and Dzud

Introduction

Climate change can create an especially complex vulnerability in cold climate regions. There are a number of factors that contribute to this trend. Primarily, due to the harsh environment in cold climate areas, there is a special relationship that develops between the residents that live there, their built environment and nature. People in such regions are dependent on natural resources and cycles and must therefore accommodate their environment. That relationship however, means that structures and patterns of foraging or cultivation have been built and developed to suit the current climate (Ford, 2010; Instanes et al., 2005; NRTEE, 2009; US Arctic Research Commission, 2003). This sort of climate-specific design does not generally allow for the redundancy and flexibility that are needed to accommodate a changing climate. To add to this vulnerability, changes are occurring at a faster rate than residents can adapt to them and the affected communities are often too isolated to receive adequate assistance from the rest of the nation (Ford, 2010; Paskal, 2010).

This case study will examine vulnerabilities in two different cold regions and their adaptive capacity. In Northern Canada, the focus will be on infrastructural vulnerabilities. For the Mongolian Dzud, it is the vulnerability of pastoral animal husbandry to extreme events. For both, adaptation is already required. The northern territories in Canada have witnessed the demise of several ice roads – important transportation arteries that ensure supplies and contact with the rest of the country- because the ice could not maintain a desired level of thickness. Similarly, hunting, foraging and agricultural traditions are no longer able to sustain Northern communities. In Mongolia, the widespread deaths of both domestic and wild animals occur in Dzud because of hunger, freezing and exhaustion. Dzud also represents a high risk to health and livelihoods of the herders, economy of the country. The larger the scale and the longer the duration of Dzud, the higher the mortality of the livestock and greater negative impacts on socio-economy (AIACC AS06, 2006).

The Canadian North

In recent years, the northern regions of Canada have experienced the most rapid rates of climate warming in the country (Furgal and Prowse, 2008; McBean et *al*., 2005; Ford and Pearce, 2010; NRTEE, 2009). These trends are consistent with global ones, as the arctic regions have been warming at twice the rate as the rest of the world and faster than the most extreme projections had predicted (Anisimov *et al*., 2007; Environment Canada, 2010).[1] In 2004, the Arctic Climate Impact Assessment estimated that the Northwest passage would be completely open by the year 2050. In reality, this area has been navigable for the past four summers and an open channel is expected before 2020 (NRTEE, 2009). The accelerated rate of climate change is creating challenges for the communities in the North because they are unable to adapt quickly enough to match the emerging impacts. This trend will likely continue. According to the 2009 study by the Canadian National Round Table on the Environment and the Economy (NRTEE), annual average temperature is expected to rise by between 1 and 3° C over the next ten years. Specifically however, winter temperatures are set to rise by between 3 and 11°C with smaller changes projected for spring and summer, with temperatures rising to as warm as -7°C in the far North (NRTEE, 2009). In more southern regions, temperatures could extend into the positive realm. All three territories, the Yukon, Northwest Territories and Nunavut, are currently struggling to adapt to such drastic changes.

[INSERT FOOTNOTE 1:
http://www.apegga.org/Members/Presentations/AC2010/HeatherAuldEnvCanPermafrost.pdf]

The Canadian North Built Environment and Impacts of Climate Change

Infrastructure adaptation is very important because of the role that infrastructure plays in maintaining the social and economic functions of a community; the amount of money that is required to operate and maintain structures; and the long lifespan of each structure. Two main climate-related impacts that affect infrastructure are permafrost thaw and snow load. Addressing these impacts is a complex task as each impact affects different structures differently. In addition, there is a negative synergistic relationship between the impacts, whereby the combined effect is more damaging than that of the individual impact itself. For example, although increasing snow loads can have negative impacts on infrastructure on their own, the fact that many buildings have been structurally weakened by permafrost thaw, adds to the damage potential during any snow event.

Permafrost thaw

Permafrost thaw is one of the leading concerns in climate-related vulnerability because it is such an all-encompassing issue. As the temperature increases, permafrost, which requires consistent sub-zero temperatures to maintain its form and density, begins to thaw. The rate of thaw and the related implications for infrastructure stability depend on the temperature increase and the type of soil underneath the permafrost (Nielson, 2007). The following figure (Figure 9-2) highlights the different permafrost zones in Canada. Under a changing climate, it is difficult to tell where permafrost is most likely to thaw, but about half of Canada's permafrost zones are sensitive to small, short-term increases in temperature, causing soil to lose it's 'bearing capacity' (Nielson, 2007; NRTEE, 2009). Municipalities in the Discontinuous or Sporadic zones are likely to feel the impacts of a warming climate since permafrost is already in a non-continuous state within their region.

Permafrost thaw affects different types of infrastructure in radically different ways. In municipalities like Iqaluit, Nunavik and Yellowknife the following impacts have been observed (Nielson, 2007; NRTEE, 2009; Infrastructure Canada, 2006):

- Roads and airport runways have suffered from erosion, heaving, buckling and splitting.
- In Iqaluit, 59 houses have required foundation repair and/or restoration and other buildings have been identified as needing attention in the near future.
- Underground pipes and cables have been damaged by shifting and heaving earth, causing disruption to both the power and communication industries.
- Water distribution and wastewater treatment systems have experienced minor damages to their underground pipes and storage facilities.
- Underground containment structures that are used to manage toxins and tailings from mining operations, have begun to show signs of vulnerability related to permafrost thaw.

[INSERT FIGURE 9-2 HERE:
Figure 9-2: Canada's Permafrost Zones (NRTEE, 2009).]

The impacts of permafrost thaw on infrastructure have implications for the health, economic livelihood, safety and 'liveability' of northern Canadian communities. The costs of repairing and installing new technologies to adapt to climate change in existing infrastructure can range from several million, to multiple billions of dollars, depending on the extent of the damage and the type of infrastructure that is at risk (Infrastructure Canada, 2006). These costs are well beyond the financial reach of many communities (and indeed most provincial/territorial governments as well), thus limiting adaptive capacity in Northern municipalities.

Snow loading

In most Northern Canadian communities, buildings and roadways are built using historical snow load standards (Nielson, 2007; Auld and MacIver, 2005). This makes them particularly vulnerable since snow loads are expected to increase with higher levels of winter precipitation (NRTEE, 2009). Already in the Northwest Territories, 10% of public access buildings have been retrofitted since 2004 to address critical structural malfunctions. An additional 12% of buildings are on high alert for snow load-related roof collapse (Environment Canada, 2010). As permafrost continues to thaw, greater impacts will be linked to the increase in snow loads.

Adaptation Responses by Government and Community in Response to These Vulnerabilities

Government and community leaders have put emphasis on action and preparedness. The money required to relocate communities provides a strong deterrent for complacency. Where necessary, relocation will be utilized as a last resort. Though each tier tackles the issue from a different angle, their approaches are proving complementary. This section will explore adaptation efforts from each level of government and the contribution they make to adaptive capacity in Northern Canadian communities.

Federal level

The Canadian government contributes to adaptation efforts through provision of assistance after a disaster or in order to relocate structures. Also, consideration is being given to the incorporation of climate change into the 2015 version of the National Building Code (Auld, 2011) which would help ensure that future infrastructure is built to a more appropriate standard and that adaptive measures are incorporated into the design and building of any new infrastructure. This would also help ensure that adaptation measures are implemented in a uniform way across the country.

Another adaptation initiative that has come from the federal level is the site-selection guidelines developed by the Canadian Standards Association (Environment Canada, 2010). Though voluntary, this set of guidelines encourages engineers, land-use planners and developers to consider environmental factors including the rate of permafrost thaw and type of soil, when building. Additionally, it strongly encourages the use of projections and models in the site-selection process, instead of relying on extrapolated weather trends (Environment Canada, 2010).

Provincial/territorial level

The territorial governments are contributing to the protection of infrastructure in two main ways:

- Conducting and funding research to identify vulnerable areas and populations, as well as feasible adaptation strategies
- Implementing adaptation options such as thermosyphons in government run buildings.[2] There have been approximately 85 flat loop thermosyphon foundations constructed into Territorial-owned buildings including schools and hospitals, prisons and visitors centres in Nunavut, Northwest Territories and the Yukon (Holubec, 2008).

[INSERT FOOTNOTE 2: Thermosyphons work by allowing the base of a building to be placed directly on the ground (Environment Canada, 2010). They help prevent permafrost thaw through passive cooling.]

The installation of thermosyphon technology is not, in itself, a long-term strategy but merely prolongs the lifetime of most infrastructure, as they last for approximately 40 years depending on the speed of permafrost thaw (Environment Canada, 2010). In addition, though they can be used successfully to protect again permafrost thaw in buildings, they cannot protect other types of infrastructure (Environment Canada, 2010).

Municipal level

The municipal level is often the most involved in building adaptive capacity and implementing adaptation strategies because they are the closest to the damage caused by climate-related impacts. Municipalities, community groups and businesses all over the three Territories have contributed to this process in many ways. Some examples are:

- *Insulated lining* underneath a 100 metre section of runway to prevent damage from permafrost thaw – Yellowknife, NWT (Infrastructure Canada, 2006)
- *Wind deflection fins* to prevent snow loading on roofs and obstructions around exits- NWT (Waechter, 2005 - http://www.rwdi.com/cms/publications/16/t05.pdf)
- *Urban planning and design* to reduce exposure to wind and snowdrifts as well as minimize heat loss from buildings – Iqaluit, NU (NRCAN, 2010 - http://adaptation.nrcan.gc.ca/case/iqaluit_e.php)
- *Construction of new bridges and all-weather roads* to replace ice roads that are no longer stable – All three territories (Infrastructure Canada, 2006)
- *Use of shims or pillars* to elevate buildings making them less vulnerable to permafrost thaw – All three territories (USARC, 2003)
- *Concrete mats bound together with chains* to limit erosion – Tuktoyuktak NWT (Johnson et al., 2000)

Communities in Northern Canada need greater adaptive capacity to cope with climate-related impacts. Despite the complexity of such impacts however, a concerted effort from three tiers of government and community can work to reduce the vulnerability of infrastructure and Northern communities.

<u>Nomadic Peoples and the Dzud</u>

The Dzud, the Mongolian term that refers to unusually difficult winter conditions, is a long-lasting cold phenomenon that has disastrous implications for nomadic pastoralism. These events usually occur following a summer drought, and can result in the death of significant numbers of livestock and wild animals due to hunger, freezing and exhaustion [Marin 2008, 2010]. The Dzud also represents a high risk to the health and livelihoods of the herders, as well as the national economy. The Dzud is characterized by summer drought followed by a snowy autumn; extremely low temperatures in the winter, and drifting windstorms in the spring that prevent livestock from grazing (NAMHEM, JEMR 2000).

Dzud Event of 2009-10: Impacts, Preparedness, and Relief

In the summer of 2009, 60 percent of Mongolia suffered from drought conditions leaving the limited pasturelands overgrazed and restricting haymaking and foraging abilities of the residents. Drought is an important pre-condition of a Dzud since it means that animals and humans alike are unable to adequately prepare for the coming winter (Jigmiddorj, 2010). In this weakened state, they are more susceptible to disease and cold. In the winter of 2009-2010, 81 percent of country suffered from conditions of heavy snow storms and extreme cold. By February 2010 the northern part of Mongolia was 3.0-6.3ºC colder compared to climatic norms, 90 percent of the country was snow covered and 40 percent covered by 30-49 cm of snow (Jigmiddroj, 2010).

About 57 percent of all country herders' households and their livestock were affected by Dzud (Batbold, 2010). About 8.1 million heads of livestock were lost and by end of April, 2010, 8,711 households had lost all their animals, 32,756 households had lost more than half of their animals, and more than 1,400 households had migrated from rural area to towns in order to seek work (Batbold, 2010). In order to survive the impacts of the severe winter and drought, many herders were forced to take loans from commercial banks such that nearly 41% of the 170,000 herders' households ended up in debt equivalent to $US45M (Batbold 2010).

Additionally, the equivalent of $US18.7M was spent for aid and relief activities by the government for animal fodder, transportation, herders' medical and social services, disposing of animal carrions to prevent outbreaks of disease, and rehabilitation of roads and mountain passes blocked by snow (Batbold 2010). The 2010 annual livestock census accounted one forth of Mongolia livestock losses from this Dzud event (NSO 2010).

Recent History of Dzud

The Dzud of 2009-10 was one of several recent events. In 1999-2000, the Dzud covered 70% of the country and caused serious damage to animal husbandry (NAMHEM, JEMR, 2000). It was especially devastating because livestock were already lean from the previous winter Dzud and had little chance to recover to withstand the harsh climate. A substantial number of livestock perished from starvation and exhaustion as well as from cold. To compound the problems, the movement of animals to better pasture was done improperly resulting in trampling of pasture.

After 3 consecutive years of dzud 2000-2002, 12,000 herders' families had lost all of their livestock, and thousands of families were subsisting below the poverty line. Mongolia's gross agricultural output in 2003 had decreased by 40% compared to that in 1999 and its contribution to the national gross domestic product (GDP) decreased from 38% to 20% (Dzud Impact 2004, AIACC, 2006). Nationally, Mongolia had lost nearly one third of its livestock, including half of cattle and 37% of horses. The living Standard Measurement surevy of 2002-2003 showed poverty incident of 36.3 percent for the urban popualtion and 43.4 percent for the rural population (JEMR 2004).

In addition to the effects of the Dzud on cattle, the cold climate had dangerous impacts on the residents in the region. Given that the food supply was so low (with animals dying off and cropland unable to support food production), the Mongolian people suffered from lack of food. The poverty and unemployment related to the loss of the herder's livelihood meant that healthcare was unavailable to a greater proportion of the population. Finally, in response to the harsh climate changes, a growing proportion of the resident population migrated (NAMHEM, JEMR 2000; AIACC AS06, 2006; NCRMSAP 2009, MARCC 2009).

Projections of Future Dzud

Climate-change models project increases in air temperature of around 4.7°C and winter precipitation by from 4 to 10%. This combination unfortunately indicates an expected increase of both drought conditions in the summer and storms in the spring, fall and winter months. Additionally, this type of change could contribute to a shifting of natural zones, increase of desert area and decrease of steppe and forest area, leaving around 70% of the country in desert conditions (MARCC 2009).

Efforts to Mitigate and Reduce Dzud Losses

The experience of increased Dzuds in recent years has produced lessons learned from the experience and recommendations to reduce risk from these events. These tools have guided the national and local governments, professional organizations, herders, and donor and aid organizations and urged them to take the practical measures towards implementation of adaptation strategies. The following section will discuss contributions at the local, nation and international levels.

National level

The recent national climate change assessment report set government strategy priorities for implementation of the adaptation measures in agriculture and water resource sectors: (i) Education and awareness campaigns between the decision makers, agriculture people and public; (ii) Technology and information transfer to farmers and herdsmen; (iii) Research and technology to ensure the agricultural development that could successfully deal with various environmental problems; (iv) Management measures by coordinating information of research, inventory and monitoring. There are still many uncertainties in direct and indirect effects of climate change on natural resource base and agriculture components, in evaluation and development adaptation options and in adaptation technologies that usually require large initial investments. Additionally, the benefits of adaptation measures are not immediately observable. These factors make it difficult to ‘sell’ adaptation funding to the public [MARCC 2009].

Local level

The NCRMSAP [2009] considers the importance of practical actions at the local level that address the needs of those most affected by climate change; in particular women, the elderly and children. It further sets a goal to build climate resilience through reducing risk and facilitating adaptation in priority sectors in the short, medium and long term. Actions for facilitation of adaptation within the animal husbandry sector include the following:

- Improve access to water and water management through region specific activities such as rainwater harvesting, and creation of water pools from precipitation and flood waters, for use with animals, pastureland and crop irrigation purposes
- Improve the quality of livestock by introducing local selective breeds that produce more and are more resilient to climate impacts
- Improve quality of livestock by strengthening veterinarian services to reduce animal diseases/parasites and cross-border epidemic infections
- Using traditional herding knowledge and techniques, adjust animal types and herd structure to be appropriate for the carrying capacity of the pastureland and pastoral migration patterns

These approaches require collaboration from public and private sectors, herder groups, members of civil society and local government (Ykhanbai et., al., 2004), herders participatory early warning system with use of modern communication technology (Oyun, 2005, Togtokh, 2011, Wang Xiaoli, Ronnie Vernooy, 2011).

International level

International level assistances aim to support an appropriate response to short-term needs and continue to deepen medium-term initiatives that reduce herder vulnerability. This can be achieved by improving pasture management and winter preparedness, the transfer and mitigation of risks from Dzud and strengthening the post-disaster response system. For instance, in winter 2010 the World Bank has mobilized resources to help the Government of Mongolia address the emerging disaster. The Bank representatives have met partners, including the United Nations and are taking immediate action that includes exploring opportunities to tap into the World Bank's global disaster response fund, working within the Bank-financed Sustainable Livelihoods Program to provide support under the pasture risk management and community initiatives funds, components of the project; and using the Index Based Livestock Insurance project which covers some 5,600 herders in the country, including in affected areas, to provide some relief to those insured (Arshad Sayed, 2010).

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Case Study 9.2.7. Disastrous Epidemic Disease: The Case of Cholera

Background

Weather has a wide range of health impacts and plays a role in the ecology of many infectious diseases. The overall relationship between weather and disease is complex and often indirect, as the case of cholera illustrates.

Weather and Health

Weather and disease have a complex relationship. As is the case with other impacts explored in this report, not all extreme health impacts associated with weather necessarily result from extreme weather events. While severe weather often has significant public health impacts (Noji 2000), some severe health impacts result from less dramatic weather events. These impacts are typically indirect, as opposed to the direct health impacts of severe weather, e.g. traumatic injuries associated with storms that are direct results of exposure to kinetic energy, and are mediated by a constellation of factors. Underdeveloped health and other infrastructure, poverty, and political instability interact with severe weather to worsen health impacts, sometimes to a disastrous degree. Cholera provides a clear example of a climate-sensitive disease, largely perpetuated by poverty and associated factors, that may become more widespread and as the climate continues to change. In addition to shifting ecological conditions to favour increased cholera exposure, climatic shifts may introduce new stresses that increase cholera prevalence and widen its geographic range. Poverty reduction and improvements in engineering, critical infrastructure, and political stability and transparency can interrupt this chain of events, increasing resilience to extreme health impacts from such climate sensitive disease.

Background: Cholera's Human Ecology

Cholera has a very long history as a human scourge. The world is in the midst of the seventh global pandemic, which began in Indonesia in 1961 and is distinguished by continued prevalence of the El Tor strain of the *Vibrio cholerae* bacterium; the current annual global burden of disease is estimated at 3–5 million cases and 100,000–130,000 deaths (Zuckerman, Rombo et al. 2007; World Health Organization 2010). Primarily driven by poor sanitation, cholera cases are concentrated in areas burdened by poverty, inadequate sanitation, and poor governance. Between 1995-2005, the heaviest burden was in Africa, where poverty, water source contamination, heavy rainfall and floods, and population displacement were the primary risk factors (Griffith, Kelly-Hope et al. 2006).

V. cholerae is flexible and ecologically opportunistic, enabling it to cause epidemic disease in a wide range of settings and in response to climate forcings (Koelle, Pascual et al. 2005). Weather, particularly seasonal rains, has long been recognized as a risk factor for cholera epidemics. Cholera is one of a handful of diseases whose incidence has been directly associated with climate variability and long-term climate change (Rodó, Pascual et al. 2002). One driver of cholera's presence and pathogenicity is the El Niño Southern Oscillation (ENSO), which brings higher temperatures, more intense precipitation, and enhanced cholera transmission. ENSO has been associated with cholera outbreaks in coastal and inland regions of Africa (Constantin de Magny, Guegan et al. 2007), South Asia (Constantin de Magny, Guegan et al. 2007), and South America (Gil, Louis et al. 2004). There is concern that climate change will work synergistically with poverty and poor sanitation to increase cholera risk.

The Risk of Disastrous Cholera Epidemics

As with other disasters, the risk of disastrous cholera epidemics associated with weather events can be decomposed into hazard probability and population vulnerability, which can be further broken down into exposure probability, population susceptibility, and adaptive capacity. Here we focus on factors affecting vulnerability.

Exposure

Cholera epidemics occur when susceptible human hosts are brought into contact with toxigenic strains of *V. cholerae* serogroup O1 or serogroup O139. A host of ecological factors affect *Vibrio cholerae*'s environmental prevalence and pathogenicity (Colwell 2002) and the likelihood of human exposure (Koelle 2009). In coastal regions, there is a commensal relationship between *Vibrio cholerae*, plankton, and algae (Colwell 1996). Cholera bacteria are attracted to the chitin of zooplankton's exoskeletons, which provides them with stability and protects them from predators. The zooplankton feed on algae, which bloom in response to increasing sunlight and warmer temperatures. When there are algal blooms in the Bay of Bengal, the zooplankton prosper and cholera populations grow, increasing the likelihood of human exposure. Precipitation levels, sea surface temperature, salinity, and factors affecting members of the marine and estuarine ecosystem, such as algae and copepods, affect exposure probability (Huq, Sack et al. 2005). Many of these factors appear to be similar across regions, although their relative importance varies, such as the association of *V. cholerae* with chitin (Pruzzo, Vezzulli et al. 2008) and the importance of precipitation and sea level (Emch, Feldacker et al. 2008). For example, marine and estuarine sources were the source of the pathogenic *V. cholerae* strains responsible for cholera epidemics in Mexico in recent El Niño years (Lizarraga-Partida, Mendez-Gomez et al. 2009).

Other variables associated with increased exposure likelihood, including conflict (Bompangue, Giraudoux et al. 2009), population displacement, crowding (Shultz, Omollo et al. 2009), and political instability (Shikanga, Mutonga et al. 2009). Many of these factors are actually mediated by the more conventional cholera risk factors of poor sanitation and lack of access to improved water sources and sewage treatment.

Population Susceptibility

Population susceptibility includes both physiological factors that increase the likelihood of infection after cholera exposure, as well as social and structural factors that drive the likelihood of a severe, persistent epidemic once exposure has occurred. Physiologic factors that affect cholera risk or severity include malnutrition and co-infection with intestinal parasites (Harris, Podolsky et al. 2009) or the bacterium *Helicobacter Pylori*. Infections are more severe for people with blood group O, for children, and for those with low physiologic reserve. Waxing and waning immunity as a result of prior exposure has a significant impact on population vulnerability to cholera over long periods (Koelle, Rodo et al. 2005).
While physiologic susceptibility is important, social and economic drivers of population susceptibility persistently seem to drive epidemic risk. Poverty is a strong predictor of risk on a population basis (Ackers, Quick et al. 1998; Talavera and Perez 2009), and political factors, as illustrated by the Zimbabwe epidemic, are often very important drivers of epidemic severity and persistence once exposure occurs. Many recent severe epidemics exhibit population susceptibility dynamics similar to Zimbabwe, including in other poor communities (Hashizume, Wagatsuma et al. 2008), in the aftermath of political unrest (Shikanga, Mutonga et al. 2009), and following population displacement (Bompangue, Giraudoux et al. 2009).

Adaptive Capacity

Cholera outbreaks are familiar sequelae of complex emergencies. The disaster risk management (DRM) community has much experience with prevention efforts to reduce the likelihood of cholera epidemics, containing them once they occur, and reducing the associated morbidity and mortality among the infected. Best practices include guidelines for water treatment and sanitation and for population-based surveillance (The Sphere Project 2004).

The 2008 Zimbabwe Cholera Outbreak

Zimbabwe has had cholera outbreaks every year since 1998, with the 2008 epidemic the worst the world had seen in two decades, affecting approximately 100,000 people and killing well over 4,500 (Mason 2009). The outbreak began on 20 August 2008, slightly lagging the onset of seasonal rains, in Chitungwiza city, just south of the capital Harare (World Health Organization 2008). In the initial stages, several districts were affected. In October, the epidemic exploded in Harare's Budiriro suburb and soon spread to include much of the country, persisting well into June 2009, and ultimately seeding outbreaks in several other countries (see Figure 9-3). Weather appears to have been crucial in the outbreak, as recurrent point-source contamination of drinking water sources (World Health Organization 2008) was almost certainly amplified by the onset of the rainy season (Luque Fernandez, Bauernfeind et al. 2009). In addition to its size, this epidemic was distinguished by its urban focus and relatively high case fatality rate (CFR; the proportion of infected people who die) ranging from 4-5% (Mason 2009) (see Figure 9-4). Most outbreaks have CFRs below 1% (Alajo, Nakavuma et al. 2006). Underlying structural vulnerability was also central: the government, paralyzed after a failed presidential election, had not been providing basic water and sanitation services for months, inflation was rampant, and political infighting undermined response efforts. Medical and public health staff, whose salaries no longer constituted a living wage, were extremely scarce. Harare's Central Hospital closed in November in 2008, at the epidemic's height, and clinics had no potable water and asked patients to bring their own (Peta 2008).

[INSERT FIGURE 9-3 HERE:
Figure 9-3: Regional spread of the 2008 Zimbabwe epidemic.]

[INSERT FIGURE 9-4 HERE:
Figure 9-4: Case fatality rates for Zimbabwe by district.]

Disease Risk Management

There are several risk management considerations for preventing cholera outbreaks and minimizing the likelihood that an outbreak becomes a disastrous epidemic. Public health has a wide range of interventions for preventing and containing outbreaks, and several other potentially effective interventions are in development. As is the case in managing all climate-sensitive risks, the role of institutional learning is becoming ever more important in reducing the risk of cholera and other epidemic disease as the climate shifts.

Conventional Public Health Strategies

The conventional public health strategies for reducing cholera risk are: primary prevention, or prevention of contact between a hazardous exposure and susceptible host (promoting access to clean water and reducing the likelihood of population displacement, for instance); secondary prevention, or prevention of symptom development in an exposed host (such as vaccination); and tertiary prevention, or containment of symptoms and prevention of complications once disease is manifest (including dehydration treatment with oral rehydration therapy).

Newer Developments

Enhanced understanding of cholera ecology has enabled development of predictive models that perform relatively well (Matsuda, Ishimura et al. 2008) and fostered hope that early warning systems based on remotely sensed trends in sea surface temperature, algal growth, and other ecological drivers of cholera risk can help reduce risks of epidemic disease, particularly in coastal regions (Mendelsohn and Dawson 2008). Strategies to reduce physiologic susceptibility through vaccination have shown promise (Calain, Chaine et al. 2004; Chaignat, Monti et al. 2008; Lopez, Clemens et al. 2008; Sur, Lopez et al. 2009) and mass vaccination campaigns have potential to interrupt epidemics (World Health Organization 2006), and may be cost effective in resource-poor regions or for displaced populations where provision of sanitation and other services has proven difficult (Jeuland and Whittington 2009). Current WHO policy on cholera vaccination holds that vaccination should be used in conjunction with other control strategies in endemic areas and be considered for populations at risk for epidemic disease, and that cholera immunization is a temporizing measure while more permanent sanitation improvements can be pursued (World Health Organization 2010). Ultimately, given the strong association with poverty, continued focus on development may ultimately have the largest impact on reducing cholera risk.

The Role of Learning

Managing disease risk, like other risk management processes, will necessarily become more iterative and adaptive as climate change introduces greater variability into familiar systems. Learning is an important component of this iterative process (see Chapter 1).

There are multiple opportunities for learning to enhance risk management related to epidemic disease. First, while reactive containment processes can be essential for identifying and containing outbreaks, this approach often glosses over root causes in an effort to return to the status quo. As the World Health Organization states, “Current responses to cholera outbreaks are reactive, taking the form of a more or less well-organized emergency response”, and prevention is lacking (World Health Organization 2006). Without losing the focus on containment, institutional learning could incorporate strategies to address root causes, reducing the likelihood of future outbreaks. This includes continued efforts to better understand cholera’s human ecology to explore deeper assumptions, structures, and policy decisions that shape how risks are constructed. In the case of cholera, such exploration has opened the possibility of devising warning systems and other novel risk management strategies. Another equally important conclusion – one that experts on climate’s role in driving cholera risk have emphasized (Pascual, Bouma et al. 2002) – is that poverty and political instability are the fundamental drivers of cholera risk, and emphasis on development and justice are risk management interventions, as well.

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Case Study 9.2.8. Cities Climate Change Response: Coastal Mega-Cities Vulnerability

Introduction

Cities are one of the major drivers of climate change due to their high energy consumption, land use, waste generation and other activities that result in the release of the vast majority of greenhouse gases. [UN HABITAT, 2008] Cities cover less than 1% of the earth's surface, but are home to around 50% of the world's population (WWF, 2009). At the same time, cities, and especially the urban poor in the developing world, are particularly vulnerable to natural disasters such as storms, floods, heat waves, and earthquakes, and man-made air pollution and waste [UEPB 2009].

Many mega-cities are situated in low-lying coastal or river-delta regions (e.g., Adelekan, 2006). Already stressed by rapid population growth and economic, social, health and cultural difficulties, developing coastal mega-cities are now increasingly vulnerable due to climate change, which has heightened the risk of disasters to cities and neighboring regions. High waves and storm surges can erode shorelines, damage dykes, and flood coastal communities, rice paddies, and aquaculture facilities. The impacts of other extreme events on coastal zones, like tropical cyclones (typhoons or hurricanes), are expected to increase due to sea level rise and changes in weather intensity—larger peak winds, heavier precipitation, and greater frequency—associated with climate change. A recent OECD report ranked global mega-cities (Nicholls et al., 2008) in terms of population and disaster vulnerabilities. The IPCC (Nichols et al., 2007) concludes: "*The impact of climate change on coasts is exacerbated by increasing human-induced pressures (very high confidence)";* and *"Adaptation for the coasts of developing countries will be more challenging than for coasts of developed countries, due to constraints on adaptive capacity (high confidence)."* The IPCC Synthesis Report (2007) considered that mangroves, salt marshes and coral reef ecosystems are *likely* to be especially affected by climate change.

Climate-change vulnerabilities of cities and settlement are mainly related to extreme weather events rather than to gradual climate change (very high confidence). Changes in current and projected climate change in extremes like tropical storms, storm surge, extreme rainfall, riverine floods, heat and cold waves and drought could impact the cities and settlements (Willbank et al, 2007)

Background

People living in slums and including those without adequate urban infrastructure are particularly vulnerable and will be among those that suffer the most from the adverse effects of climate change. Rising temperatures coincide with increased energy use for cooling. The loss of green cover in cities, in the form of parks, trees and agricultural land, raises urban temperatures, and also contributes to climate change [UEPB 2009]. However, some steps are being taken to adapt urban planning to environmental change. In China, for example, as of 2009, 40 eco-cities were in development (4 smart-grid pilot cities, 21 LED-street-light cities, 13 electric-vehicle cities). Cities vary in size, economic capacity, geographic location, and access to resources within the country and internationally. Therefore, each city's specific local conditions must be taken into account when determining the most appropriate policies for that particular city [UEPB 2009].

A common theme in the Copenhagen Diagnosis (2009) is that changes are happening more rapidly than earlier predictions accounted for, so that a risk management approach will be necessary in planning adaptation strategies for coastal cities. Adaptation strategies for the most vulnerable urban areas need to be a priority (Schipper and Burton, 2009). There is also a need to build human resource capacity to deal with climate-related hazards (McBean and Rodgers, 2010), combined with disaster risk reduction approaches.

Vulnerability of Cities to Climate Change

Cities in Megadeltas

Vulnerabilities to extreme weather events in megadeltas in a context of multiple stresses: the case of Hurricane Katrina. The development in some densely populated megadeltas of the world will be challenged by climate change depending on the adoption of appropriate adaptation measures. The experience of the U.S. Gulf Coast with Hurricane Katrina in 2005 is considered a good example of the impact of a tropical cyclone – of an intensity expected to become more common with climate change – on the demographic, social, and economic processes and stresses of a major city located in a megadelta. In 2005, the city of New Orleans had a population of about half a million, located on the delta of the Mississippi River along the U.S. Gulf Coast. The city is subject not only to seasonal storms but also to land subsidence at an average rate of 6 mm/yr rising to 10-15 mm/year or more. Embanking the main river channel has led to a reduction in sedimentation leading to the loss of coastal wetlands that tend to reduce storm surge flood heights, while urban development throughout the 20th century has significantly increased land use and settlement in areas vulnerable to flooding. A number of studies of the protective levee system had indicated growing vulnerabilities to flooding, but actions were not taken to improve protection Willbanks et al (2007)

Climate Change and Adaptation in Asian Coastal Cities

The World Bank, ADB and JICA funded case studies for Asian coastal cities such as Bangkok, Ho Chi Minh City, Kolkata and Manila which are at risk due to flooding. The cities have been examined by the A1FI and the B1 scenarios as likely high-low cases and the outputs showed i) increase factors such as mean temperature, precipitable water, extreme 24-hour precipitation, and seasonal mean precipitation; ii) robust linear relationship between the local temperature increase and the global mean temperature increase; iii) precipitable water in the four megacity areas increases at a rate of ~ $8\%/^0K$ or larger. iv) For return periods larger than about 10 years, the IPCC models projected extreme 24-hr precipitation change ranges from ~ $3\%/^0K$ to ~ $28\ \%/^0K$; and concluded that the uncertainty in precipitation extremes is much larger than in temperature or precipitable water (Masahiro, 2008).

Climate change risk and vulnerability of cities are different. For instance, the economic damage of flooding in Bangkok is projected to rise roughly four-fold in 2050, and 70% of this cost would be attributed to land subsidence alone. About one million inhabitants of Bangkok and Samut Prakarn will be affected, and one in eight of the affected inhabitants will be from the condensed housing areas where most live below the poverty level. The Bangkok city lies in the Chao Phraya River Basin and has tropical monsoon climate with 1,130 mm average annual precipitation varying from 1,000 mm to 1,600 mm. Here flooding is driven by high seasonal rainfall events over 2 to 3 months. Recent floods have occurred in 2002 and 2006 (Masahiro, 2008).

Adaptation and Preparedness of Cities to Climate Change

City adaptation measures vary depending on political, cultural, historical and climatic conditions. Such measures can include placing a greater emphasis on coastal resource management, especially the protection of mangrove and natural reef ecosystems; and a concerted “hardening up” of infrastructure, including storm-drainage systems, water supply and treatment plants, protection or relocation of solid waste management facilities, and energy generation and distribution systems. Coastal cities will likely need to plan for and invest in heavy physical infrastructure projects specifically related to sea-level rise. These include: sea-surge protective barriers and dams, the reconstruction of harbour facilities, better early warning and rapid response systems to prepare for disaster preparedness as well as building better levees, flood barriers such as the Thames barrier in the UK (Lavery and Donovan 2005) and prevention facilities and improving flood and coastal defence management. In regions where droughts are more likely to occur, better water saving and water management measures will be required (UNEP, UN Habitat, 2009; Simonovic, 2009). The adaptation options developed for the Asian megacities include both structural and non structural measures (see Table 9-4) (Masahiro, 2008).

[INSERT TABLE 9-4 HERE:
Table 9-4: Example of adaptation options (Masahiro, 2008).]

Coastal defences have traditionally relied on “hard defence” structures such as sea walls, dykes and tidal barriers. Those adaptation strategies dependent on engineering and technology can have significant economic costs and negative impacts on biodiversity (Campbell *et al*, 2009). It was recognized in the IPCC (2007) that those structures can alter sediment deposition, prevent inland migration of vegetation in response to seal level rise, and damage salt marshes. Coastal protection adaptation strategies range from ’hard defence’ to ‘soft defence’ such as natural resources management (Adger *et al* 2007). ‘Hard defence’ are manmade coastal structures used to reflect large amounts of wave energy and hence protect the coastline and soft engineering defence solutions incorporate activities such as dune and wetland restoration, planting of marsh vegetation and mangroves, and the conservation and/or sustainable management of those mentioned ecosystems, including coral reefs and sea grasses. From a practical point of view, both hard and soft defences need to be integrated to facilitate adequate adaptation. Biological diversity can play an important role in the soft coastal defence solutions. The Convention on Biological Diversity (2009) states that the resilience of biodiversity to climate change can be enhanced by reducing non-climatic stresses in combination with conservation, restoration and sustainable management strategies of the ecosystems. This can be achieved through a reduced dependency on the hard approach (e.g. intrusive coastal development, alternation, imposed land use practices) while empowering a soft approach wherever appropriate.

Cities are attempting to address a broad set of issues including the provision of basic urban services, road construction, managing urban growth, open spaces, coastal protection and other environmental objectives [UEPB 2009]. These initiatives illustrate a CCA and DRR combined approach to mitigate hazards (Henstra and McBean, 2008). UN-HABITAT’s experience dealing with sustainable urban development facilitated the local and international level exchanges with the global Sustainable Urban Development Network (SUD-Net) and the Cities in Climate Change Initiative (CCCI).

In addition to physical and infrastructural adaptations, a broad range of targeted vulnerability reductions also contribute to climate change adaptation. These include: local economic development strategies; better shelter options and in-situ slum upgrading; relocation of urban populations to appropriate or improved locations when in-situ upgrading is not feasible; better health facilities and better public health interventions; and additionally, the improvement of agricultural production systems including the promotion of urban agriculture and strengthening rural-urban linkages [UNEP, UN Habitat, 2009].

However it is important to acknowledge that because of their concentrated form and efficiencies of scale, cities offer major opportunities to reduce energy demand and minimize pressures on surrounding lands and natural resources. If cities can harness the energy and creativity of their citizens and build on the inherent advantages that urbanization provides, they can, in fact, be part of the solution to the global problems of poverty and environmental degradation. [World Resources 1996-97].

International Initiatives for Cities and Climate Change

United Cities and Local Government (UCLG) is the global voice of cities and the main local government partner of the UN, spearheading the UN Advisory Committee of Local Authorities (UCLG, 2009). The Cities for Climate Protection (CCP) campaign—operated by ICLEI: Local Governments for Sustainability—has a membership of 1100 local governments from 68 countries around the world. It provides cities with tools and assistance for policies and quantifiable implementation measures on emission reductions, better air quality and more livable cities; and organized the first World Congress on Resilient Cities, bringing together multiple level stakeholders around cities and climate change (http://www.iclei.org). The Local Government Climate Roadmap is a process started by global local government associations, which advocates a strong and comprehensive post-2012 climate agreement. It emphasizes the critical role of cities in implementing climate change policies.

The UNEP and UN HABITAT Sustainable City Programme (SCP/LA21) directly helps local authorities and their partners to achieve a well-managed urban environment as part of a sustainable urban development process that empowers all city dwellers promoting good environmental governance at all levels – locally, nationally, regionally, and globally. In addition, through the Cities in Climate Change Initiative (CCCI), conducted a joint assessment of city vulnerability to climate change, using systematic and structured methods and a broad participatory approach. After early pilot assessments in 4 cities such as Sorosogon (Philippine), Maputo (Mozambique), Kampala (Uganda), and Esmeraldas (Ecuador) the initiative was expanded for other cities of developing and least developed countries (UNEP, UN HABITAT, 2009).

The United Nations International Strategy for Disaster Reduction (UN ISDR) is working with its partners to raise awareness and commitment for sustainable development practices as a means to reduce disaster risk and to increase the wellbeing and safety of citizens- to invest today for a safer tomorrow. Building on previous years' campaigns focusing on education, school, and hospital safety, ISDR partners are launching a new campaign in 2010 – Making Cities Resilient – to enhance awareness about the benefits of focusing on sustainable urbanization to reduce disaster risks. The campaign will seek to engage and convince city leaders and local governments to be committed to a checklist of Ten Essentials for Making Cities Resilient and to work on these together with local organizations, grassroots networks, the private sector and national authorities. (UN ISDR, 2010)

Conclusions

Coastal mega cities are one of the major drivers of climate change but at the same time are the worst victims of the climate change impacts. People living with un-adapted and inadequate infrastructure and housing are at most risk, constituting a significant percentage of the urban population. Without targeted adaptation, the impacts will however be felt indiscriminately in both developed and poor countries and will hinder the road to sustainable development. In coastal megacities, the adaptation could be integrated and extended to cover coastal zone and/or the flood plain. In the face of a dwindling resource base, growing demand/use for resources, and increasing environmental extremes, 'soft coastal defense' should be encouraged and promoted whilst possibly considering reducing investment in 'hard defense' structures where appropriate (Campbell *et al*, 2009). The biodiversity based adaptation measures coupled with "mixed defenses" are receiving increased attention in developing countries, particularly Small Island Developing States (SIDS), where adaptive capacity is low and local communities depend upon their natural resources (Cherian, 2007). The situation is similar for the Least Developed Countries (LDCs).

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Case Study 9.2.9. Small Islands Developing States and Least Developed Countries: The Limits of Adaptation

<u>Introduction</u>

Small Island Developing States (SIDS) are small island and low-lying coastal countries that share similar development challenges, including small but growing populations, lack of resources (e.g. freshwater, land, soils), economic dependence on international markets, and high susceptibility to natural disasters (SIDSNET). SIDS are therefore among the most vulnerable states to the impacts of climate change and particularly to both natural and man-made environmental disasters, as they have a limited capacity to respond to and recover from such disasters.

Since 1971, the United Nations has designated a category of States as 'Least Developed Countries' (LDCs), including those that are deemed highly disadvantaged in their development process (many of them for geographical reasons), and more than other countries face the risk of failing to come out of poverty. As such, the LDCs are considered to be in need of the highest degree of attention on the part of the international community.

Around 25% of the LDCs are the SIDS and the LDCs and the SIDS share several characteristics: high levels of poverty, serious environmental degradation, and low human and institutional capacities for integrated and sustainable land management.

Vulnerabilities of SIDS and LDCs

Many SIDS face specific disadvantages associated with their small size, insularity, remoteness and proneness to natural hazards. SIDS are particularly vulnerable to the physical impacts of climate change, especially the increased frequency and intensity of droughts, floods, and hurricanes (Read, ICTSD 2010). Indeed, their key economic sectors such as agriculture, fisheries and tourism are among the most susceptible to the impacts of climate change. Therefore, climate change threatens to exacerbate existing vulnerabilities and hinder their socio-economic development. In addition, the hazards of extreme weather events are coupled with other long-term climate change impacts, especially sea-level rise. Low-lying atoll communities, such as the Maldives and Cook Islands, are especially vulnerable (Woodroffe, 2007, Ebi, et al 2006). As a result, small island states and particularly atoll countries are likely to experience erosion, inundation and saline intrusion resulting in ecosystem disruption, decreased agricultural productivity, changes in disease patterns, economic losses and population displacement, all of which reinforces their increased vulnerability to extreme weather events (Nurse and Sem, 2001), (Pernetta J.C., 1990). SIDS are also home to many diverse and local minority communities who depend on ecosystem services that are negatively impacted by extreme weather events.

Within the LDCs, due to lower adaptive capacity, poor communities are more vulnerable to the negative effects of climate change, including drought, which is a concern given that climate-related disasters have become more frequent (Seck et al. 2005, UN 2009). Disaster risk is configured unevenly and is concentrated in the poorest countries, and among the poorest communities within countries (UN, 2009; Adger et al. 2007). For example, at the global level low-income countries represent 13 percent of the exposure and 81 percent of disaster mortality risk (UN, 2009). Small Island Developing States (SIDS) and Land-Locked Developing States (LLDCs) suffer higher relative levels of economic loss from natural hazards—and they are less resilient to those losses so that one extreme event can set back decades of development gains (UN, 2009; Kelman, 2010).

Due to low resilience, high susceptibility to harm, and limited adaptive capacity, the poor are particularly vulnerable to climate hazards and the negative impacts of climate change (Adger, 2006). Much current research has emphasized that there are multiple stressors and multiple pathways of vulnerability, particularly those that address the social and institutional dynamics of social-ecological systems—for example, while some famines may be triggered by extreme climate events such as drought or floods, vulnerability researchers have shown that famines and food insecurity are more often caused by disease, war or other factors (Adger, 2006). In short, the social and economic characteristics by which LDCs are defined (education, income and health, for example) effectively lower the threshold for extreme climate events (Adger et al 2007).

Underdevelopment and susceptibility to disasters are mutually reinforcing: disasters not only cause heavy losses to capital assets, but also disrupt production and the flow of goods and services in the affected economy, resulting in a loss of earnings. In both the short and the long-term, those impacts can have sharp repercussions on the economic development of a country, affecting gross domestic product (GDP), public finances, foreign trade as well as price indices, thus contributing further to increasing levels of poverty and indebtedness (Mirza, 2003; Ahrens and Rudolph, 2006).

Examples of Impacts on the Vulnerable System of SIDS and LDCs, and Measures Taken to Reduce Vulnerability

Mahe Island, Seychelles

In January 2004, torrential rains brought about a serious flood in Au Cap District on Mahe Island in Seychelles. The heavy rains caused extensive damages to properties and other infrastructure, agriculture, and business. The President of the Republic put together a task force to study the problem and analyze solutions and associated costs. The study showed that Seychelles will need about 4 million rupees (US$ 800,000) to remedy drainage problems in Au Cap District alone, and that long-term disaster resilience will require a much broader set of initiatives, including setting up early warning systems, updating emergency management plans, a maintenance programme for drainage systems, and capacity-building in emergency management and technical fields such as hydrology and flood forecasting. The findings of the task force indicate that SIDS must take seriously the need for resilience-building and technical capacity strengthening, which for many states requires best-practices and information-sharing networks with countries with more expertise. The flooding, a stark example of an extreme weather event, has created an awareness in Seychelles regarding these capacity-building needs (UN DESA, Code 57).

Republic of the Marshall Islands

Fresh water availability is a major concern for many SIDS, like the Republic of the Marshall Islands (RMI). And because SIDS are especially vulnerable to extreme weather events, their water supplies face the challenges of rapid salinization due to seawater intrusion and contamination. The Marshall Islands, for example, lack the financial and technical resources to implement seawater desalination for their population, impeding the efficient sustainable recovery of freshwater from groundwater and increasing their susceptibility to extreme climate change events. Because simple abstraction of freshwater from thin groundwater lenses, a typical practice in oceanic atolls, often results in upward coning of saltwater, which in turn causes contamination of the water supplies, a new welling procedure was required in RMI. Therefore, with the help of the United Nations and the North American National Weather Service (part of the National Oceanic and Atmospheric Administration, NOAA), a new scavenger technology for wells was introduced. This proved to be of great help against saltwater contamination of fresh groundwater in three different test locations. Since the technique is relatively simple, it is a potential solution against saltwater contamination of freshwater lenses in a wide range of coastal regions. RMI has benefited from its use of new, pioneering technology to limit the effects of extreme weather events on its water supply, and from its partnerships with leading international bodies to devise and implement complex technological projects (UN DESA, Code 326).

The Maldives

The Maldives consists of 1,192 islands, at least 80 percent of which are 1 meter or less above sea level, and only three of which have a surface area of more than 500 hectares. These characteristics make them highly vulnerable to sea level rise and extreme weather events. Tourism, which accounts for about 33 percent of GDP, creates employment for roughly half of the population and stimulates economic activity in other sectors such as agriculture, construction, and services. About 20 percent of the population depends on subsistence fisheries. The economic and survival challenges of the people of the Maldives were evident after the 2004 tsunami caused damage equivalent to 62 percent of national GDP. As of 2009, the country still faced a deficit of more than US$150 million for reconstruction. Such devastation in a SIDS might be countered with further disaster preparation and efforts to maintain emergency funds to rebuild their economies (De Comarmond and Payet, 2010).

Malawi

Malawi is one of the more drought-prone countries in southern Africa, and its predominantly smallholder farmers are severely affected by rainfall risk resulting in food insecurity. In the past, the government has responded to recurrent drought-induced food crises by providing ad hoc food relief. Until recently, droughts and a lack of credit have prevented Malawian farmers from planting higher-yielding seed types, but an experimental weather insurance programme (based on a precipitation index and bundled with loans) allowed farmers to access hybrid groundnut seeds. Such safety nets have allowed farmers to plant the higher-yielding seeds (Linnerooth-Bayer and Mechler, 2007).

Ethiopia

Since 2004, the Government of Ethiopia and its international partners have also been piloting a weather index risk financing programme as a form of drought risk mitigation and transfer. Ethiopia's innovation was to link the short-term relief (insurance) with the Government's employment-based Productive Safety Nets Programme (PSNP), which addresses the predictable needs of chronically vulnerable groups who require assistance during the hunger gap season even in good years (Maxwell et al., 2010).

Grenada

Grenada is a small tri-island state in the Eastern Caribbean with a population of 102,000, of which 9,000 live on the two sister islands of Carriacou and Petite Martinique, and a per capita gross national product of US$7,959. It is a small open economy that is vulnerable to external shocks and natural disasters as seen by the effects of 9/11, Hurricane Ivan, which devastated the economy in 2004, and Hurricane Emily, which struck in 2005. Hurricane Ivan brought major disruption to an economic recovery process, and Hurricane Emily followed 10 months later, virtually completing the trail of destruction started by Ivan. The hurricanes impacted on every sector of the economy and society with devastating force. In both the economic and social sectors, the capital stock was severely damaged bringing the overwhelming majority of income, employment, and foreign exchange activities to a halt. Assessment of the damages from Hurricanes Ivan and Emily by Grenada's Agency for Reconstruction and Development and the Ministry of Finance was set at US$1.2 billion, representing over 250% of the country's GDP (UNDP, CPAP 2006-2009).

Policy and Management Practices

The importance of disaster risk-reduction strategies is apparent. It is necessary to move from post-disaster reactions to building capacity for prevention. Many SIDS examined tended to suffer worse disasters when they lacked early warning systems. Early warning and information systems at regional and sub-regional levels are appropriate. Such systems, however, depend on functioning and accurate regional climate observation systems, which also need to be established among SIDS and other stakeholders. Further expanding international cooperation for the development of early warning and information systems within the context of broader disaster prevention efforts might need to be sensitive enough to meet the needs of small states, especially the SIDS (UN, 2005).

Disaster reduction strategies are aimed at enabling societies at risk to become engaged in the conscious management of risk and the reduction of vulnerability. It is important to acknowledge that communities may have chosen to live with this risk because the costs of mitigating them are simply unobtainable to them. Macro scale diversification filtering down to local levels may facilitate vulnerable communities obtaining the means to mitigate for disasters. Therefore these policies should be culturally and gender sensitive and could be considered for political commitment. They involve the adoption of suitable regulatory and other legal measures, institutional reform, improved analytical and methodological capabilities, financial planning, education and awareness. Development plans and poverty reduction strategies in SIDS, including disaster risk assessment as an integral component, could be considered as sensible precautions by Member States and international organizations. This could help to ensure that their investments to reduce risk and vulnerability of development gains are not lost. For disaster risk reduction to be strengthened in SIDS both a humanitarian and a development responsibility in line with the Millennium Development Goals would be beneficial. Member States could be encouraged to support the process of consolidation of ISDR in SIDS as a valuable instrument for sustainable development (UNISDR, 2004).

The Southwest Indian Ocean (SWIO) is characterized with strong southeast monsoon variability which impacts negatively on the water resources, activities and economy of the islands. To improve a deeper understanding of the transient equatorial convective waves during southern hemisphere winter will form an important component of the research in enhancing scientific understanding on the causes and mechanisms governing climate variability in the SWIO during southeast monsoon. The results could be useful for strengthening numerical model performances in the near equatorial tropical region of the Indian Ocean. Results will be made available to forecast centres, policy makers, water resource managers, agricultural and tourist managers to ensure wide application such that national capacities related to disaster mitigation, prevention and preparedness are strengthened and future risk of climate are reduced. Outcomes are expected to provide platforms for improved prediction skills, better water resources management, and improvement in environmental data observation in the Southwest Indian Ocean and in formulating downstream enhancement of water storage facilities. Many SIDS can benefit from such international scientific collaboration to improve their disaster resilience and understanding of potential threats (UN DESA, Code 58).

Although climate change-specific policies seem marginal compared to the pressing issues of poverty alleviation, hunger, health, economic development and energy needs, it is becoming increasingly clear that progress toward the development goals can be seriously hampered by climate change. This is why the linkages between development and climate change now receive more and more attention in scientific and policy circles (Davidson et al., 2003; OECD, 2010).

Catastrophic and irreversible damage to humans can result even from modest changes in natural systems or relatively small climate hazards. The impact on a community depends on the latter's adaptive capacity, which is in turn shaped by the community's policies and institutions (Heltberg et al., 2008). Complicating matters, the interests of poor communities are not necessarily the same as those of poor government (Kates, 2000). Some (Kates, 2000; Carmen Lemos and Tompkins, 2008; Davies et al., 2008, Heltberg et al., 2008) have argued that policy instruments based upon social protection are best suited for adaptation and long-term risk reduction because they generate net benefits under all future climate scenarios and they are rooted in the specific needs of a particular community and can therefore build resilience by addressing the root causes of vulnerability.

Progress in carrying out analyses and identifying what needs to be and can be done can be documented, but action on the ground to support mainstream adaptation to climate change remains limited, particularly in the least developed countries. National policy making in this context remains a major challenge. This might be best met with appropriate increased international funding for adaptation and disaster management (Yohe et al, 2007; Ahmad and Ahmed, 2002; Jegillos, 2003; Huq et al., 2006).

Socio-economic and even environmental policy agendas of developing countries do not yet prominently embrace climate change (Beg et al., 2002) even though most developing countries participate in various international protocols and conventions relating to climate change and sustainable development and most have adopted national environmental conservation and natural disaster management policies (Yohe et al, 2007). Social and environmental (climate change) issues are, however, often left resource-constrained and without effective institutional support when economic growth takes precedence (UNSEA, 2005).

<u>Lessons Identified</u>

Central to nearly all the assessments of key vulnerabilities is the need to improve knowledge of climate sensitivity—particularly in the context of risk management—the right-hand tail of the climate sensitivity probability distribution, where the greatest potential for key impacts lies (Schneider et al., 2007). In addition, relatively few regional and sub-regional climate change scenarios have been derived from regional climate models or empirical downscaling for Africa, primarily due to restricted computational facilities and a lack of human resources and climate data (Boko et al. 2007). Global climate models are unable to simulate the teleconnections and feedback mechanisms responsible for rainfall variability in Africa, and other factors (dust aerosol concentrations, sea-surface temperature anomalies) complicate African climatology (Boko et al 2007).

Finally, despite renewed momentum and commitments by governments to reduce disaster risk in the face of major catastrophes, preventive approaches continue to receive less emphasis than disaster relief and recovery (Davies et al., 2008). To the extent that disaster risk reduction and are advocated as cost-effective means of preventing future negative impacts on development investments without simultaneously addressing equity and rights-based arguments, they may fail to capitalize on potential synergies (Davies et al., 2008).

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Case Study 9.2.10. Risk Transfer: The Role of Insurance and Other Economic Approaches to Risk Sharing

Introduction

The use of insurance and financial mechanisms is part of effectively preparing for, responding to, and recovering from extreme events and disasters. Additional understanding of current and projected risks, including exposure to extreme events and increasing vulnerability is needed. Knowing and be able to project risk in order to ascertain effective financial mechanisms is part of risk transfer mechanisms. Actual or potential barriers to implementing these methods exist and there are considerable challenges constrain the effectiveness of current risk management strategies and policies.

There are only a small number of examples as yet, of programmes that contribute to risk reduction, and use insurance tools. These do indicate that it is possible to design measures to work towards that aim but there is need for research into how to more effectively bring disaster risk reduction and insurance together, building on experience mostly from industrialised countries.

Although a number of factors continue to constrain the rate of convergence, spending on insurance is growing faster in most developing countries than in industrial countries. One constraining factor is that property owners in developing countries have not yet developed knowledge about insurance and its role in managing risk. In addition, the current state of insurance regulation is weak in most developing countries relative to international standards of best regulatory practice and consumers do not yet have confidence in financial institutions. To date most actions to bring insurance to the world's poorest people have initially focused on life and health insurance products, like funeral and disability coverage, and motor vehicle insurance. This may, in time, create the basis that can be extended eventually to address risks to property and crops. It is not yet clear whether the role of humanitarian assistance and international relief following a disaster, which have largely been directly to address the urgent priorities of rebuilding schools, hospitals and public infrastructure, undermines the responsibilities of the local governments to address these concerns on an ongoing basis.

The process of recovering from extreme events is expensive and can take years or even decades. Financing mechanisms supporting economic recovery include insurance and humanitarian assistance. These systems, however, have been challenged and sometimes overwhelmed in recent years by a combination of climate change, increasing populations living in areas of risk, ageing infrastructure and other factors. This case study describes a number of recent examples seeking to strengthen and enhance the financial and humanitarian systems in place to support recovery for extreme weather events. Warner et al. (2010) provide a review of the connections between climate change adaptation and disaster risk reduction in the context of insurance and risk transfer mechanisms, which provided the basis for this case study report.

There are several examples of financial mechanisms for managing risks at different scales, from local to national to international levels (see Table 9-5). At the local level, the focus is on individual households, small-to-medium sized enterprises (SMEs), farms and similar institutions or organizations. At national, including sub-national, the focus is on governments while at the international level, development organizations, donors, non-governmental organizations and others need to be considered. Broadly-speaking**,** risk transfer mechanisms can be grouped as non-insurance and insurance mechanisms. In this case study, the main focus is on insurance mechanisms

[INSERT TABLE 9-5 HERE:
Table 9-5: Examples of mechanisms for managing risks at different scales (Linnerooth-Bayer and Mechler, 2009)**.**]

Insurance is the primary source of funds to support recovery from extreme weather events in developed countries. Today insurance covers 40 percent of disaster losses in the industrialised counties compared to only around 3 percent in developing countries (Hoeppe and Gurenko, 2006). The share is higher for homeowners and businesses, and for many events covers all of the damage incurred. In contrast, most governments and their agencies typically choose not to purchase insurance coverage for the risk of damage to public infrastructure. Insurance markets are only emerging in most developing nations. Affluent homeowners and businesses account for most and perhaps all of the insurance market in many countries. Public infrastructure is largely uninsured.

<u>Description of Risk Transfer Tools and their Relation to Disastrous Events</u>

There are several forms of risk transfer tools (Cummins and Mahul, 2009) and these include:

- (Traditional) Insurance - is a contractual transaction that guarantees financial protection against potentially large loss in return for a premium.

- Micro-insurance (e.g., Morelli et al., 2010) - is characterised by low premiums or coverage and is typically targeted at lower income individuals who are unable to afford or access more traditional insurance. Micro-insurance tends to be provided by local insurance companies with some external insurance backstop (e.g. reinsurance).
- Catastrophe Reserve funds - are typically set up by governments, or may be donated, to cover the costs of unexpected losses.
- Risk pooling or pools - aggregate risks regionally (or nationally) allowing individual risk holders to spread their risk geographically. Through spreading risks, pooling allows participants to gain catastrophe insurance on better terms and access collective reserves in the event of a disaster.
- Insurance-linked securities - most commonly catastrophe (cat) bonds which offer an avenue to share risk more broadly with the capital markets.
- Weather insurance typically takes the form of a parametric (or indexed-based) transaction, where payment is made if a chosen weather-index, such as 5-day rainfall amounts, exceeds some threshold. Such initiatives minimise administrative costs and moral hazard and allow companies to offer simple, affordable and transparent risk transfer solutions.

<u>Analysis of Information Available on the Role of Thematic Approach in Specific Cases</u>

Over the past decade there have been a number of examples of insurance mechanisms emerging in developing countries that will support recovery from future extremes. In each area there have been encouraging signs that insurance may, over time, grow to support the risk management needs in developing countries like that in place in industrial countries. Despite the growth in this sector, there are still market gaps and failures that exist, making the contributions of national governments and the international community an important factor in disaster recovery.

Caribbean Catastrophe Risk Insurance Facility

The Caribbean Catastrophe Risk Insurance Facility (Young, 2009), the world's first regional insurance fund, was launched in 2007, with sixteen participating countries securing insurance protection against damage from catastrophic hurricanes and earthquakes, the two most serious risks in the area. Seven of the participating countries represent almost one third of the countries identified by the World Bank as experiencing the greatest economic losses from disasters during the period from 1970 to 2008 when measured as a share of GDP.

The Caribbean Facility focuses primarily on insuring participating governments seeking to pay 50 percent of the costs that the governments are expected to incur and thus provides an incentive for governments to invest in risk reduction and other risk transfer tools. The cost of participation is determined for each participating country based upon estimates of the expected risk and extent of damage. Pooling the risks of 16 countries has reduced by 40 percent the costs relative to the price each government would have paid if they negotiated individually in the commercial insurance market. Funding for the program is the responsibility of participating countries and has largely been supported a donor conference hosted by the World Bank.

The experience with the Caribbean Facility shows that programs must reflect the needs of the participating countries. Severe weather risk is a growing dimension of the risks facing governments in developing countries but there will be circumstances where it is appropriate to establish mechanisms that also address other hazards. The Facility also provides an example where international assistance can be provided to support disaster management yet designed to support a transition where local government assume a possibly growing responsibility.

Micro-Insurance

A recent report (Morelli et al., 2010) has reviewed the role of micro-insurance in disaster risk management. There are many examples of micro-insurance emerging to cover life, health and motor insurance needs in developing countries, but the application to disaster risk management is only beginning. Loster and Reinhard (2010) focus on the relationship between micro-insurance and climate change. Most examples of micro-insurance involve organizations active in communities without insurance that develop insurance products and evolve this into formal insurance companies. While some early micro-insurance companies operate on a for profit basis, many are not for profit. Most are based on the expectation that the pool of participants will provide payments that cover the costs incurred, including expected damage claims, administrative costs, taxes, regulatory fees, etc. The expected damage claims from most people with low incomes are very low because claim events are rare, by definition, and these people typically have fewer possessions that may be damaged.

A major challenge for the micro insurance operations that have been established recently has been controlling the cost of administration. Some organizations have addressed this issue by selling insurance to groups of people. Some programs are linked to loans, increasing their credit-worthiness. Bhatt et al (2010) describe the how micro-insurance has emerged in a policy environment that has made recent progress towards disaster risk reduction and can put cash into the hands of affected poor households so they can begin rebuilding livelihoods. Recent insurance regulatory reforms within the Indian Government and the prioritization of risk reduction by national and global practitioners have contributed to the viability and advancement of micro-insurance for the poor. In Malawi, smallholder farmers can purchase index-based drought insurance linked to loans used to enhance their farm productivity.

Index-Based Insurance in Bolivia

An index-based insurance program in Bolivia promotes risk reduction by encouraging farmers to assess their practices relative to a reference farmer to determine if poor outcomes are due to environmental factors, triggering an insurance payout, or other factors within the farmer’s control. The Fundación PROFIN has developed a scheme in four provinces in the north and central Altiplano regions of Bolivia that combines incentives for pro-active risk reduction and an insurance index mechanism. In this scheme the index is based on the production levels of reference plots of farmland in areas which are geographically similar in terms of temperature, precipitation, humidity, and type of soil. A group of farmers identify a peer who is considered to use the best available methods. That farmer serves as a technical assistance agent and provides an indicator reference plot, to help other farmers reduce their risks and improve their yields. The system encourages other farmers to match the reference farmers in implementing risk reduction efforts to reduce the effects of drought, excess rains, hailstorms and frost. The objective becomes to perform or out-perform the reference plot by improving agricultural practices and reducing risk of damage from weather hazards (Hellmuth et al., 2009).

<u>Role of Disaster Risk Reduction and Climate Change Adaptation Related Activities</u>

Risk knowledge and public awareness of that risk are foundations of any risk management strategy. Insurers and public authorities can work together in increasing public awareness by collecting and providing high quality information about hazard risks and helping to translate this awareness into real action. Potential barriers and challenges include the technical difficulties related to risk assessment, dissemination of appropriate information and overcoming education and language barriers in some areas. It is important that premiums appropriately reflect the risk as otherwise this can provide a disincentive for risk reduction. The Caribbean Disaster Mitigation Project (CDMP) is an example of poor take-up while flood-risk, low-lying polder areas in The Netherlands are a positive example (Botzen et al., 2009).

Insurance solutions and the involvement of the insurance industry can contribute to the establishment of appropriate regulatory frameworks, for example through building codes and planning practices that account for relevant risks and climate change impacts. Examples are the Florida state premium discount initiative, Association of British Insurers case, Turkish Catastrophe Insurance Pool and the All India Disaster Mitigation Institute which ties micro-insurance to disaster prevention and reduction measures. Barriers to effective regulation may be a lack of good governance, institutional capacity or adequate legal and enforcement structures. Public intervention in insurance markets must also be balanced to facilitate the development of competitive markets (e.g. to keep costs down) and to ensure that insurance is allowed to be actuarially sound. The United Nations Environment Programme Finance Initiative (2009; p. 20) has proposed expanding the application of insurance mechanisms for adaptation.

Learning and Lessons Identified

The current experience in developing countries of the benefits of insurance for managing risks from (climate-related) natural hazards and in promoting risk reduction remains promising but limited. Insurance is growing rapidly there but it is not clear whether all programmes spontaneously achieve the benefits of reaching the most vulnerable, building resilience and reducing indirect and longer-term losses.

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Case Study 9.2.11. Promoting Disaster Risk Reduction and Adaptation through Education, Training, and Public Awareness

Introduction

Disasters can be substantially reduced if people are well informed and motivated towards a culture of disaster prevention and resilience (UNISDR 2005). Disaster risk reduction education encompasses primary and secondary schooling, training courses, academic programmes, and professional trades and skills training (UNISDR 2004), community based self-assessment, public discourse involving the media, awareness campaigns, exhibits, memorials and special events (Wisner 2006). Given the broad scope of the topic, this case study illustrates practices in primary school education, training programmes and awareness-raising campaigns in various countries.

Overview of Education, Training, and Awareness

The Hyogo Framework calls on States to "use knowledge, innovation and education to build a culture of safety and resilience at all levels" (UNISDR 2005). States, however, report minor progress in implementation (ISDR 2009). Challenges noted include the lack of capacity among educators and trainers, difficulties in addressing needs in poor urban and rural areas, the lack of validation of methodologies and tools and little exchange of experiences. On the positive side, the 2006-2007 international disaster risk reduction campaign "Disaster Risk Reduction Begins at School",[3] furthered and raised awareness of the importance of the education agenda across some countries (ISDR 2009). Furthermore, the United Nations Decade of Education for Sustainable Development 2005-2014 calls for improving the knowledge base on disaster prevention and reduction as one of the keys to sustainable development.

[INSERT FOOTNOTE 3: The 2006-2007 international disaster risk reduction campaign 'Disaster Risk Reduction Begins at School at: http://www.unisdr.org/eng/public_aware/world_camp/2006-2007/wdrc-2006-2007.htm]

To personalize information and elicit behavioural change, risk reduction programmes not only impart knowledge of the natural hazards but also engage students in identifying and reducing risk in their surroundings. Disaster education should not be confined within the school but could be beneficially promoted to be shared with families and communities (Shaw *et al*., 2004). Lectures can create knowledge, particularly if presented with visual aids and followed up with conversation with other students. Yet it is family, community and self-learning, coupled with school education, that transform knowledge into behavioural change (Shaw *et al*. 2004).

Countries are increasingly incorporating disaster risk reduction in the curriculum (ISDR 2009). The following programme in the Philippines brings together disaster risk reduction and climate change education.

Integrating Disaster Risk Reduction and Climate Change in the Curriculum (Philippines)

The Asian Disaster Preparedness Centre (ADPC) and UN Development Programme (UNDP), with the National Disaster Coordinating Council and support from ECHO, assisted the Ministry of Education in Philippines, Cambodia and Lao PDR to integrate disaster risk reduction into the secondary school curriculum. Each country team developed its own draft module, adapting it to local needs. The Philippines added climate change and volcanic hazards into its disaster risk reduction curriculum. The relevant lessons addressed "what is climate change, what is its impact, and how you can reduce climate change impact." Other lessons focus on the climate system, typhoons, heat waves, landslides, among other related topics (Luna *et al*. 2008).

The Philippines' final disaster risk reduction module was integrated into 12 lessons in science and 16 lessons in social studies of first year of secondary school (Grade 7). Each lesson includes group activities, questions to be asked to the students, the topics that the teacher should cover in the lecture, a learning activity in which students apply knowledge gained and methodology for evaluation of learning by the students (Luna *et al*. 2008).

Under this project, 1020 students, including 548 girls, were taught the disaster risk reduction and climate change module. 23 teachers participated in the four-day orientation session. An additional 75 teachers and personnel were trained to train others and replicate the experience across the country (Luna *et al*. 2008).

Training for DRR and Adaptation

In order to effectively include disaster risk reduction and adaptation in the curriculum, teachers require (initial and in-service) training on the substantive matter as well as the pedagogical tools (hands-on, experiential learning) to elicit change (Wisner 2006, Shiwaku *et al*. 2006). Education programme proponents might have to overcome teachers' resistance to incorporate yet another topic into overburdened curricula. To enlist teachers' cooperation partnership with the ministry of education and school principals can be helpful (UNISDR 2007, World Bank 2009). The following programme in Indonesia and the evaluation results from Nepal demonstrate the importance of engaging teachers for effective education. The subsequent example from Nepal, Pakistan and India focuses on training builders through extensive hands-on components in which new techniques are demonstrated and participants practice these techniques under expert guidance (World Bank 2009).

Teacher training in Indonesia

The Disaster Awareness in Primary Schools project was launched in Indonesia in 2005 with German support and is ongoing. By 2007 through this project, 2200 school teachers had received disaster risk reduction training. Project implementers found that existing teaching methods were not conducive to active learning. Students listened to teacher presentations, recited facts committed to memory and were not encouraged to understand concepts and processes. The training took teachers' capabilities into account by emphasizing the importance of clarity and perseverance in delivering lessons so as to avoid passing on faulty life-threatening information (such as on evacuation routes). Scientific language was avoided and visual aids and activities encouraged. Teachers were asked to take careful notes and to participate in practical activities such as first-aid courses, thus modeling proactive learning. Continuity with the teachers' traditional teaching methods was maintained by writing training modules in narrative form and following the established lesson plan model. Moreover, to avoid further burdening teachers' heavy lessons requirements and schedules, the modules were designed to be integrated into many subjects, such as language and physical education, and to require minimum preparation (UNISDR 2007).

Evaluation of teacher training in Nepal

A survey of 130 teachers in 40 schools in Nepal revealed that disaster risk education depended on the awareness of individual teachers. Teaching focused on the effects of disasters that the teachers could relate to from personal experience. The study concluded that teacher training is the most important step to improve disaster risk education in Nepal. Eighty percent of social studies teachers reported a need for teacher training but the study recommends that training programs should be designed to integrate DRR into any subject rather than taught in special classes (Shiwaku *et al*. 2006).

Training of builders in Nepal, India and Philippines

The National Society for Earthquake Technology (NSET) in Nepal conducted large-scale training for masons, carpenters, bar benders and construction supervisors over a five-month period to train them on risk-resilient construction practices and materials. Participants from Kathmandu and five other municipalities formed working groups to train other professionals. As the project was successful, a mason-exchange program was designed with the Indian nongovernmental organization SEEDS. Nepali masons were sent to Gujarat, India, to mentor local masons in the theory and practice of safer construction. Also in India, the government of Uttar Pradesh trained two junior engineers of the rural engineering service in each district to carry out supervisory inspection functions and delegated the construction management to schools principals and village education committees. Similarly, the Department of Education of Philippines mandated principals to take charge of the management of the repair and or construction of typhoon-resistant classrooms. Assessment, design and inspection functions are provided by the Department's engineers, who also assist with auditing procurement (World Bank 2009).

Raising Public Awareness

In addition to the insights on the psychological and sociological aspects of risk perception, risk reduction education has benefitted from lessons in social marketing. These include: Involving the community and customizing for audiences using cultural indicators to create ownership; incorporating local community perspectives and aggressively involving community leaders; enabling two-way communications and speaking with one voice on messages (particularly if partners are involved); and evaluating and measuring performance (Frew 2002). The following examples from Brazil, Japan and the Kashmir region illustrate good practice in raising awareness for risk reduction.

Public awareness initiative: Santa Catarina, Brazil

Between 2007 and 2009, the Santa Catarina State Civil Defence Department with the support of the Executive Secretariat and the state university undertook an initiative in this southern Brazilian state to reduce social vulnerability to disasters induced by natural phenomena and human action (SCSCDD 2008a,b).

During the two-year initiative, 2000 educational kits were distributed free of charge to 1324 primary schools. Students also participated in a competition of drawings and slogans that was made into a 2010 calendar. As the project's goal was public awareness of risk, the project jointly launched a communications network in partnership with media and social networks to promote better dissemination of risk and disasters (SCSCDD 2008a,b).

The initiative also focused on the most vulnerable populations. A pilot project for 16 communities precariously perched on a hill prone to landslides featured a 44-hour course on risk reduction. Community participants elaborated risk maps and reduction strategies. Shortly into the course, heavy rains battered the state triggering a state of emergency. 10 houses in the pilot project area had to be removed and over 50 remain at risk. Participants were surprised how quickly they had to put to use their risk reduction knowledge. Their risk reduction plans highlight the removal of garbage and large rocks as well as the building of barriers. The plans identified public entities for partnership and costs for services required. The training closed with a workshop on climate change and with the community leaders' presentation of the major risk reduction lessons learned (SCSCDD 2008c).

On international disaster risk reduction day, representatives of the community, Civil Defence and other public entities, visited the most at-risk areas of the hill community, planted trees, installed signs pointing out risky areas and practices, distributed educational pamphlets and discussed risk. One of the topics of discussion was improper refuse disposal and the consequent blocking of drains, causing flooding (SCSCDD 2008d).

Public awareness campaign in Saijo, Japan

In 2004, Saijo City in the Ehime Prefecture of Shikoku Island was hit by record typhoons that led to flooding in its urban areas and landslides in the mountains. A small city with semi-rural mountainous areas, Saijo City faces unique challenges in disaster risk reduction. First, Japan's aging population represents a particular problem. Young able-bodied people are very important to community systems of mutual aid and emergency preparedness. And as young people tend to move away to bigger cities, smaller towns in Japan have an even older population than the already imbalanced national average. Second, smaller cities like Saijo City are often spread over a mix of geographic terrains – an urban plain, semi-rural and isolated villages on hills and mountains, and a coastal area (Yoshida *et al.* 2009, UNISDR 2010).

To meet both of these challenges, the Saijo City Government launched in 2005 a risk awareness programme targeting schoolchildren. Focusing on different physical environments of the city, from the mountainside to the town, the 'mountain-watching' and 'town-watching' project takes 12-year olds, accompanied by teachers, local residents, forest workers and municipal officials, on risk education field trips. The young urban dwellers meet with the elderly in the mountains to learn together about the risks Saijo City faces and to remember the lessons learned from the 2004 typhoons. Additionally, a 'mountain and town watching' handbook has been developed, a teachers' association for disaster education was formed, a kids' disaster prevention club started, and a disaster prevention forum for children was set up (Yoshida *et al.* 2009, UNISDR 2010).

The programme was conceived and implemented by the city government and is an example of a local government leading a multi-stakeholder and community-based disaster risk awareness initiative that can then become self-sustaining. The government supported the programme through providing professionals from disaster reduction and education departments, funding the town and mountain watching, and putting on an annual forum (UNISDR 2010).

Public awareness campaign: DRR and climate change education in Himalayas

CEE Himalaya is undertaking a disaster risk reduction campaign in 2,000 schools and 50 Kashmir villages. In the schools, teachers and students are involved in vulnerability and risk mapping through rapid visual risk assessment and in preparing a disaster management plan for their school. Disaster response teams formed in selected schools have been trained in life-saving skills and safe evacuation (CEE Himalayas 2010).

CEE Himalaya celebrated International Mountain Day 2009 with educators by conducting a week-long series of events on climate change adaptation and disaster risk reduction. About 150 participants including teachers and officials of the Department of Education, Ganderbal, participated in these events (CEE Himalayas 2010).

Participants worked together to identify climate change impacts in the local context, particularly in terms of water availability, variation in micro-climate, impact on agriculture/horticulture and other livelihoods, and vulnerability to natural disasters. The concept of School Disaster Management Plans (SDMP) was introduced. Participants got a hands-on opportunity to prepare SDMPs for their schools through group exercises, and discussed their opinions about village contingency plans (CEE Himalayas 2010).

Some of the observations on impacts of climate change in the area discussed by participants included the melting, shrinking and even disappearance for some glaciers, drying up of several wetlands and perennial springs. Heavy deforestation, decline and extinction of wildlife, heavy soil erosion, siltation of water bodies, fall in crop yields, reduced availability of fodder and other non- timber forest produce were some of the other related issues discussed (CEE Himalayas 2010).

Participants watched documentaries about climate change and played the Urdu version of “Riskland; Let’s Learn to Prevent Disasters”. They received educational kits on disaster risk reduction and on climate change, translated and adapted for Kashmir (CEE Himalayas 2010).

Lessons Identified in Effectively Communicating Risk Information

Based on experience of public education campaigns for disaster risk reduction, some working axioms have been demonstrated (Bonifacio *et al*. 2010):

- It could be beneficial if people could understand who is at risk, the potential and likely physical, economic, communal and cultural heritage losses, within a specific timeframe.
- When people are clearly informed about what they can do to reduce their risks, before, during and after a disaster, they are capable of understanding and remembering the basics.
- When people are convinced that their actions will make a difference and that they have the skills needed to reduce vulnerability, they are more likely to act.
- Most people are more motivated by positive examples than by fear.
- Culture is shaped by language, stories and traditions. Therefore, local knowledge can be used to transmit information.
- Children can be engaged in active, inquiry-oriented learning through exploration and play.
- Lectures, sermons and moral exhortations are not as effective as when people participate in a solution, when they believe it is their own idea.

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Case Study 9.2.12. Effective Legislation for Multilevel Governance of DRR and Adaptation

<u>Introduction</u>

The Philippines is at the forefront of a new trend to integrate climate change and disaster risk reduction legislation: not only does the new disaster risk reduction legislation address climate change, the Climate Change Law of 2009 addresses disaster risk reduction. The Philippines' new measures are of relevance to other Governments as they assess whether their own national legislation to reduce and manage disaster risk is adequate for adapting to climate change. Through an analysis of benchmark DRR laws, such as those from South Africa and Colombia, this case study explores critical provisions for good legislation, identifying key elements that are essential to the success of both disaster risk reduction and adaptation. It emphasizes useful measures for governance at various levels: from regional to national, as in the case of the European Commission directive, and from national to local levels, as exemplified by Spain and France. The elements identified can serve as a model for climate change adaptation legislation or improve existing disaster risk management legislation.

Background: What Constitutes Good Legislation for Disaster Risk Reduction and Adaptation?

A legal framework establishes policies, practices and processes for reducing and managing risk, as well as penalties and incentives for their implementation. It also assigns responsibility, empowers agencies and bodies, and assigns budget lines (Mattingly 2002; Pelling and Holloway 2006; Britton 2006). Because legislation promotes accountability and coordination, the Hyogo Framework for Action calls on Governments to adopt or modify legislation to reduce disaster risk (UNISDR 2005a). A majority of States have some form of disaster risk management legislation or are in the process of enacting it (UNISDR 2005b, UNDP 2007), but relatively few have enacted climate change legislation to date (United Kingdom, Canada, France and Philippines have specific climate change legislation).

Legislation alone does not guarantee effective implementation; however, laws that have proven effective for disaster risk reduction contain elements and provisions that can be replicated when developing or strengthening laws to adapt to climate change. One useful first step for potential climate change adaptation laws is to identify existing measures that have worked well within the State in reducing disaster risk so as to benefit from experience. Another useful measure is to assess whether a State's current DRR legislation is adequate for meeting the new challenges presented by climate change or whether a more comprehensive DRR law or a new climate change law would be most beneficial.

Elements of Effective Legislation

Some of the elements that effective DRR and adaptation laws have in common include the following:

- The law provides legal and policy coherence by explicitly linking to other laws and policies from relevant sectors and throughout all administrative levels.
- The law devolves both responsibility and funding from national to regional (and from national to local levels) with clarity about the generation of funds and procedures for accessing resources at every administrative level.
- The institutional arrangements the law establishes provide both access to power for facilitating implementation and opportunities to "mainstream" disaster risk reduction and adaptation into development plans.
- The law is based on comprehensive, up-to-date risk assessment that mandates periodic reassessment as risks evolve and knowledge of climate change impacts improves.
- The law includes provisions that increase accountability and enable coordination and implementation of disaster risk reduction and adaptation—i.e., the clear identification of roles and responsibilities, requirement to establish and maintain a national risk database, mandate to provide public access to risk information, education and training, as well as enable access to participate in decision making.

The next section illustrates these principles with specific examples.

Linked Laws and Policies across Sectors and Levels

Some States successfully implement disaster risk reduction through a number of sectoral laws, such as Sweden[4] and Slovenia.[5] Others, such as Colombia, South Africa and the Philippines, develop one overarching, comprehensive legal framework for disaster risk reduction. Although both approaches can work for individual States, many high-income developed countries reported that a challenge to reducing risk is the lack of an overarching national policy and legal framework to facilitate a holistic approach (ISDR 2009). An overarching framework can generate cost-effective policies that balance a multitude of sometimes contradictory laws and decrees, such as 20,000 legal acts in Kyrgyzstan (UNDP 2007), or Indonesia's 120 different pieces of disaster risk management related legislation (UNDP 2009).[6]

[INSERT FOOTNOTE 4: For example, the Seveso Act, The Environmental Code; The Planning and Building Act, The Land Code, the Water Directive, The Flooding Directive, And The Civil Protection Act.]

[INSERT FOOTNOTE 5: For example, the Protection Against Natural • and Other Disasters Act 3535 Official Gazette of the Republic of Slovenia, 64/94, 51/2006., The Fire Protection Act 3636 Official Gazette of the Republic of Slovenia, 71/93, 3/2007, The Fire Service Act 3737 Official Gazette of the Republic of Slovenia, 1993, 2005, The Slovenian Red Cross Act 3838 Official Gazette of the Republic of Slovenia, 7/93, The Recovery from the Consequences of Natural Disasters Act 3939 Official Gazette of the Republic of Slovenia, 75/2003, The Protection against Drowning Act 4040 Official Gazette of the Republic of Slovenia, 42/2007.]

[INSERT FOOTNOTE 6: The latter was addressed in the 2007 Disaster Management Bill that aims to provide leadership for comprehensive disaster risk reduction (UNDP ILS Indonesia 2009).]

Regional legislation, such as the European Commission's (EC) Floods Directive (2007) and Water Framework Directive (2000), both described in subsection 2 below, can also foster legislative coherence on a specific issue. The EC's Floods Directive is specifically linked to the pre-existing Water Framework Directive and includes flood risk reduction of shared river basins. At the national and sub-national level, implementation of these directives has facilitated EU members states' efforts to address simultaneously multiple processes that impact drought and flood risk, including agricultural policies and integrated water resource management, and land use (EC, 2000; EC, 2009). France, for example, created its Grenelle of the Environment with legislation that brings multiple competing stakeholder groups together to develop policies that can reduce flood and risks in a coherent manner (Deboudt, 2010; France, 2010).

South Africa and Colombia: the comprehensive legislation model

In South Africa, the 2002 Disaster Management Act provides a comprehensive framework for disaster risk reduction implementation at all levels. It defines the hierarchical institutional structure that governs disaster risk management in the country, including a cabinet committee at the apex; an advisory forum with representatives from national and provincial departments, local government, business and civil society; as well as disaster management centres at national, provincial, metro and district levels. It also establishes disaster management frameworks for all levels of government with roles and responsibilities, mandates the development of disaster management plans for each government level and the creation of a national disaster management information system (SANDMC 2007).

Similarly, Colombia has framework legislation that organizes disaster risk management in the country at all levels of government. Colombia has also enacted dozens of sector-specific laws, in particular environment, land use, housing and urban development, and education, among others, that govern and support disaster risk reduction (Vásquez 2006, Colombia Ministerio 2009).

The Philippines: the linked legislation model

The Philippines Climate Change Act was enacted in 2009 and innovates by closely linking climate change and disaster risk. At the outset, it adopts the UNFCCC's ultimate objective of stabilizing greenhouse gas emissions and the Hyogo Framework for Action's "strategic goals in order to build national and local resilience to climate related disasters." In recognizing that "climate change and disaster risk reduction are closely interrelated and [that] effective disaster risk reduction will enhance climate change adaptive capacity, the State shall integrate disaster risk reduction into climate change programs and initiatives" (Act 9729, Sec 2). The Philippines Disaster Risk Reduction and Management (DRRM) Act, enacted in 2010, conversely includes several references to climate change (Act 10121, Sec 2 (a), (d), (e), (g)).

The linkage between DRR and climate change processes in the Philippines is likely to be facilitated by both laws' references to each other and their specific references to the other's process in their mandates. For example, like the Philippines' DRRM Act, the Climate Change Act creates a commission to be chaired by the president and attached to the president's office, thus ensuring highest political support for collaborative implementation. The commission is composed by the secretaries of all relevant departments as well as the "Secretary of the Department of National Defense, in his capacity as Chair of the National Disaster Coordinating Council," and representatives from the disaster risk reduction community. Main functions of the Commission are to "[e]nsure the mainstreaming of climate change, in synergy with disaster risk reduction, into the national, sectoral and local development plans and programs" (Act 9729, Sec 9 (a)) and to create a panel of technical experts, consisting of practitioners in disciplines that are related to climate change, including disaster risk reduction" (Act 9729, Sec 10).

Devolution of Power and Funding

Because disasters and climate change impacts are experienced locally, adaptation requires the involvement of a variety of stakeholders from the public and private sectors and civil society, and there is a growing recognition that successful adaptation practices will involve the integration of strategies across sectors and within multiple scales of governance in a coordinated manner (Biesbroek et al., 2009; Biesbroek et al., 2010; Gopalakrishnan and Okada, 2007). Effective decentralization and multi-level governance of disaster risk reduction with the accompanying transfer of capacity and resources to newly accountable local actors, and parallel support could be beneficial for civil society organizations that hold local governments accountable and fill the void if those governments were to fail (Mitchell et al., 2008). The decentralization of disaster risk reduction and climate change adaptation, complemented with increased autonomy of local agencies and enhanced support of these actors from national governments and regional institutions, would have positive benefits (Baker and Refsgaard, 2007; Gopalakrishnan and Okada 2007). The following case illustrates the devolution of power from regional to national level.

Implementation of the European Commission's Water Framework Directive in Spain and its Floods Directive in France

The European Commission's Water Framework Directive (WFD) (2000) seeks to reduce the impacts of droughts and floods (EC, 2000, I(e)). The WFD's 2010-2012 work programme supports integrated implementation at multiple scales of government by identifying concrete deliverables at those scales (EC, 2009).

The WFD delegates drought risk management to member states, and in 2001 Spain enacted legislation to implement this directive and to decentralize drought risk management even further by making it the responsibility of river basin districts and local governments (Spain, 2001). Spain's National Drought Plan was the culmination of fifteen years of groundwork and planning (Spain, 2001), and in the case of the Segura River Basin the federal government delegated the responsibility for drought risk management to a local agency with nearly 70 years of experience managing drought risk. This devolution of authority is based upon the subsidiarity principle, which allocates responsibilities for policy development and implementation to the lowest level of government that can meet a given policy's objectives (Inman and Rubinfeld, 1998). Through the EC Water Framework Directive, the local authorities in the Segura River Basin are supported by a network of experts from the European Union. At the federal level the

Government of Spain supported this process of decentralization through a royal decree that gave the local water boards the authority and resources to implement emergency policies, and which established a multi-level institutional framework connecting the individual water boards with one another and with the Ministry of the Environment (Spain, 2005). To facilitate integrated implementation, the EU's Water Directors mandated that expert group identify ways to improve financing for improvements in water efficiency (EC, 2009).

In 2007, the European Commission endorsed a flood risk directive that, like its Water Framework Directive, is based on the subsidiarity principle and which calls upon each of its Member States to assess, map, and prepare for flood risk within their country (EC, 2007). By this time, the French Government had already established a general framework for coastal flood risks at the sub-national and local level. This framework for decentralized flood-risk management was developed with input from all levels of government, civil society and the private sector, and this process is being reinforced through legislation (The Grenelle of the Environment) and financing by the Barrier Fund for natural risk prevention, which is in turn funded by obligatory contributions based on the CatNat insurance premiums (Deboudt, 2010).

The decentralization process has been strengthened by legislation (the Bachelot Law) that requires:

- The dissemination of guidance material and decision-support tools;
- Local capacity development;
- Multi-level, integrated coastal zone management policies for the French littoral;
- Development of Predictable Natural Risk Prevention Plans through multi-stakeholder dialogues; and
- Clearly defined responsibilities for implementation (France 2003; France 2009; Deboudt, 2010).

Furthermore, the EC also evaluates whether flood risk management measures receive adequate funding (EC, 2009).

Other national level examples

At the national level, the Philippines Climate Change Act devolves substantial power to local government units and calls upon them to formulate, plan and implement climate change action plans and expressly authorizes local government units to appropriate and use funds from their internal revenue allotment. Additional funds of about 1.1 million USD are allocated for the implementation of the Act.

Adequate funding is tightly linked to the ability to effect risk reduction and adaptation at all levels. UNDP (2007) characterises the provision of adequate funding as the ultimate "litmus test" of government commitment to disaster risk reduction. For example, in South Africa, eight years after the promulgation of the disaster risk reduction act, most district municipalities have not established the centres required by the Act and do not have disaster risk reduction plans in place (SACoGTA 2009) mainly due to a lack of resources to cover costs related to start-up, continuous operations, disaster risk reduction projects, response recovery and rehabilitation activities, and training and capacity building programmes, which are specifically stipulated for funding in the Framework (NDMC 2009, Visser and Van Niekerk 2009; SACoGTA 2009). Reasons for the lack of funding include a lack of clarity of the Act on the funding sources for developing and maintaining the centres it establishes at all levels and the management plans they are to prepare (Visser and Van Niekerk 2009).

Similarly, in Colombia, more than 80 percent of municipalities are able to assign only 20 percent of their own unearmarked resources to risk reduction and disaster response. Because the law does not stipulate percentages and amounts, municipalities allocate minimal sums for disaster risk reduction (Colombia Ministerio 2009) given competing infrastructure and social spending needs (Cardona and Yamín 2007). Colombia's National Fund for Calamities lacks clear rules for capital accumulation and disbursement; its funding stems from unreliable sources and the national government has been reducing its budget allocation. As a result, the actions of the National System for Attention and Prevention to Disasters are limited, and the Fund's resources are directed to emergency response rather than prevention (Cardona and Yamín 2007).

South Africa's and Colombia's experiences are replayed around the world. Except for some high-income countries, Governments report a lack of systematic policy or institutional commitment to providing dedicated or adequate resources for disaster risk reduction, in particular in the absence of legislation that makes financial allocations legally binding (ISDR 2009). Even in countries, such as those discussed here, in which funding for disaster risk management is mandated by law, actual resource allocation for disaster risk reduction remains low and is concentrated in preparedness and response (UNDP 2007). Allocations to address the underlying risk factors by development sectors are not adequately documented and accounted for (UNDP 2007).

The Philippines new DRRM law aims to redress this problem. It renames the Local Calamity Fund as the Local Disaster Risk Reduction and Management Fund and stipulates that no less than 5 percent shall be set aside for risk management and preparedness. Thirty percent shall be allocated for quick response to disasters (Philippines Act 10121, sec 21 and 22). Further, to carry out the provisions of the Act, the Commission allocated one billion pesos or 21.5 million USD (Philippines Act 10121, Sec 23). Unspent money will remain in the fund to promote risk reduction and disaster preparedness.

Institutional Arrangements for Access to Power and Integration into Sectors and Development Planning

South Africa's Intergovernmental Committee on Disaster Management is established by the president and reports to the president through Cabinet on response once a disaster has occurred (SANDMC 2007). In Colombia, the robust institutional structure for risk reduction was weakened through a series of reforms that have reduced the issue's standing in the hierarchy and diminished its political importance (although recently the president convened entities at all levels to motivate them to fulfill their disaster risk reduction mandates) (Colombia Ministerio 2009). Bolivia and Nicaragua give maximum authority to the national committee headed by the president and include representatives from the major ministries, the national department of planning, civil defence, the Red Cross Society and private sector members (UNDP 2007).

The positioning of DRR and climate change adaptation institutions within the highest levels of government has proven effective because this position often determines the amount of political authority of the national disaster risk management body (UNDP 2007, ISDR 2009). National disaster risk management offices attached to prime ministers' offices usually can take initiatives affecting line ministries, while their colleagues operating at the sub-ministerial level are likely to face administrative bottlenecks (UNDP 2007). High-level support is particularly important to enable disaster risk reduction legislation to provide a framework for strategies to build risk reduction into development and reconstruction (Pelling and Holloway 2006).

Unfortunately, many governments delegate the establishment and coordination of institutional systems for disaster risk reduction to civil defence and protection organisations traditionally responsible for emergency response, which usually do not have the competence in development planning and regulation necessary to engage with other sectors nor the necessary political authority within government to do so (World Bank 2008).

South Africa is one of a handful of countries that have made a legal connection between disaster risk reduction and national development planning frameworks, and its DRR legislation requires that municipalities' Integrated Development Plans (IDPs) contain risk management plans.[7] This link is crucial because most climate-related disaster risk has been driven by poor development policies that have increased the exposure of assets—and people—to hazards (UNISDR, 2009).

[INSERT FOOTNOTE 7: Others include Comoros, Djibouti, Ethiopia, Hungary, Ivory Coast, Mauritius, Romania and Uganda (Pelling and Holloway 2006).]

In the Philippines, the highest policy-making and coordinating body for disaster management, the National Disaster Coordinating Council, which was renamed National Disaster Risk Reduction and Management Council under the new DRRM Act, sits within the Department of National Defense. To promote intersectoral integration, the DRRM Act mandates the inclusion of experts from all relevant fields as members of the Council (Philippines Act 10121, Sec. 5; Sec. 11(2)) and expressively defines its mandate on mainstreaming disaster risk reduction into sustainable development and poverty reduction strategies, policies, plans and budgets at all levels (Philippines Act 10121, Sec. 2). The Philippines Climate Change Act also addresses sectoral integration: "the policy of the State [is] to systematically integrate the concept of climate change in various phases of policy formulation, development plans, poverty reduction strategies and other development tools and techniques by all agencies and instrumentalities of the government" (Philippines Act 9729, Sec. 2).

Dynamic Assessment of Risk Knowledge

Adaptation to the impacts of climate change, such as increased exposure to climate extremes, is a challenge at administrative, temporal, and spatial scales (Adger et al., 2005; Urwin and Jordan, 2008). Therefore, effective legislation could address appropriate temporal scales and incorporate evolving information on climate change impacts and risks. Meanwhile, ensuring appropriate adaptive responses depends on this knowledge being generated, acted upon and evaluated continuously. For example, to support implementation of the WFD and Flood Directive, EC Water Directors created a Working Group on Floods (responsible for evaluating the implementation of the two directives with respect to climate change and in light of new risk maps, vulnerability assessments an flood risk assessments) and a Water Scarcity and Drought Expert Group that inputs into a Temporary Expert Group on Climate Change and Water (EC, 2009).

To ensure that legislation for disaster risk reduction and adaptation is dynamic and relevant, clauses about the periodicity of specific tasks mandated in the law can be included. For instance, the Philippines DRRM Act calls for the development of a framework to guide disaster risk reduction and management efforts to be reviewed "on a five-year interval, or as may be deemed necessary, in order to ensure its relevance to the times" (Philippines Act 10121, Sec 6 (a)). The Act also calls for the development of assessments on hazards and risks brought about by climate change (Philippines Act 10121, Sec 6 (j)). Likewise the Philippines Climate Change Act calls for the framework strategy that will guide climate change planning, research and development, extension and monitoring of activities to be reviewed every three years or as necessary (Philippines Act 9729, Sec 11). Similarly, the United Kingdom's Climate Change Act establishes the preparation of a report informing parliament on risks of current and predicted impact of climate change no later than five years after the previous report (United Kingdom Act 2008, Section 56 (1)).

Provisions for Coordination, Accountability, and Implementation

The attribution of roles and responsibilities is among the most critical functions of adaptation and disaster risk reduction legislation to ensure coordinated action and accountability. In addition to the clear hierarchies established by the legislations of South Africa, Colombia and Philippines, each entity in the hierarchy has been assigned concomitant responsibilities. Spain's application of the EC Water Framework Directive to reduce drought risk and France's flood risk reduction also define responsibilities clearly. These laws, such as France's Grenelle of the Environment, allow civil society and business also to play roles in reducing disaster risk and adapting to climate change. South Africa's, Colombia's and the Philippines' DRRM laws also include provisions for the involvement of NGOs, traditional leaders, volunteers, community members and the private sector in disaster risk reduction, and the Philippines' Climate Change Act establishes three seats for representatives from academia, business and nongovernmental organizations as well as four subnational representatives (Philippines Act 9729, Sec 5 (q-w)).

<u>Lessons Identified and Conclusion</u>

In addition to the five elements identified and illustrated above, several lessons emerge from this review to keep in mind when strengthening or developing legislation for disaster risk reduction and adaptation.

- *Need legislation for DRR and adaptation*: although policies and measures are critical to implementation, legislation promotes enforcement and accountability by codifying roles, responsibilities and expectations in a transparent manner that can be used to hold decision-makers to account.
- *Legislation takes a long time to develop; best to avoid starting from scratch*: it took decades to develop the DRR laws of South Africa, Colombia and Philippines, and Spain's National Drought Plan was the result of fifteen years of groundwork and planning, spurred on by the passage of the EC Water Framework Directive

(Spain 2001). Governments may be able to expedite the passage of effective legislation by taking stock of and then amending or building upon existing laws.

- *Political interest in climate change can be harnessed to improve national DRR law*. The UNFCCC Cancún Adaptation Framework formally recognizes DRR as an essential element of climate change adaptation and encourages governments to consider linking adaptation measures to the Hyogo Framework for Action (UNFCCC, 2010, Paragraph 14(e)). Governments may benefit by harnessing the political momentum to enhance their disaster risk governance capacities, and developing country governments can apply for adaptation financing to do so. Whether a State chooses to strengthen existing DRR law to support adaptation to climate change or develop new climate change law, it is critical to review the DRR law and its implementation for lessons.
- *When power and resources are decentralized, it is necessary to have knowledge and capacity at all levels* for implementation. The effectiveness of decentralized DRRM policies in Spain and France rely on strong institutional capacities at sub-national and local levels of government. Of equal importance, these measures have drawn upon people and institutions with decades of flood and drought risk management at the sub-national level.
- *International funding processes for adaptation will require a mechanism to ensure funds reach the local level*. Allocating finances for DRRM and adaptation measures has proven a challenge for many governments—even when they have enacted legislation whose implementation demands specific funding. Establishing independent (or semi-autonomous) expert groups to evaluate aspects of implementation—including inadequate funding—seems to be working in the EU, but it remains to be seen whether a review alone will work equally well in developing countries where resources for DRRM are already constrained. The use of Green Climate Funds to implement DRRM and adaptation legislation may be one solution given that these funds will require international reporting measures.

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Case Study 9.2.13. Early Warning Systems: Adapting to Reduce Impacts

Early Warning Systems for Disaster Risk Reduction and Climate Change Adaptation

At least since the 1990s, there has been a significant upward trend in the annual number of natural disasters (Vos et al., 2010; Munich Re 2010; Gall et al., 2009). The enormity of the problem is outlined by Wahlström (2009) who stated "*Over the last two decades (1988-2007), 76% of all disaster events were hydrological, meteorological or climatological in nature; these accounted for 45% of the deaths and 79% of the economic losses caused by natural hazards*." Floods and storms are the dominant factor in these disasters. Regardless of the extent to which this increase is attributable to changes in the frequency and intensity of natural hazards as opposed to increases in vulnerability or exposure to these hazards (e.g., the numbers of people living in areas subject to such hazards), the effect has been a substantial increase in the threat posed by weather and climate extremes on human populations around the world. Despite these increases, improvements in early warning systems have contributed to decreases in the numbers of deaths, injuries, and loss of livelihood over the last thirty years (IFRC, 2009).

An early warning system is defined[8] as "the set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss." This definition encompasses a wide range of factors are that may or, if effective, will contribute to effective responses to warnings, and emphasizes the point that an early warning system involves considerably more than just a forecast of an impending hazard. This need for more than just accurate predictions was stated in the the Hyogo Framework for Action (HFA) 2005-2015[9] which stressed that early warning systems should be *"people centered"* and that warnings need to be*" timely and understandable to those at risk"* and need to "*take into account the demographic, gender, cultural and livelihood characteristics of the target audiences*." Warnings also need to include *"guidance on how to act upon warnings."*

[INSERT FOOTNOTE 8: UNISDR Terminology on Disaster Risk Reduction, 2009: Available at http://www.unisdr.org]

[INSERT FOOTNOTE 9: Hyogo Framework for Action 2005-2015: ISDR, International Strategy for Disaster Reduction. www.unisdr.org]

In 2006, the United Nations International Strategy for Disaster Reduction completed a global survey of early warning systems. The executive summary opened with the statement that: *"If an effective tsunami early warning system had been in place in the Indian Ocean region on 26 December 2004, thousands of lives would have been saved. The same stark lesson can be drawn from other disasters that have killed tens of thousands of people in the past few years. Effective early warning systems not only save lives but also help protect livelihoods and national development gains. Over the last thirty years, deaths from disasters have been declining[10], in part thanks to the role of early warning systems and associated preparedness and response systems"*.[11]

[INSERT FOOTNOTE 10: Centre for Research on the Epidemiology of Disasters (CRED), "Thirty Years of Natural Disasters 1974-2003: The Numbers", Presses Universitaires de Louvain, 2004.]

[INSERT FOOTNOTE 11: Global Survey of Early Warning Systems. Prepared by UN International Strategy for Disaster Reduction for the United Nations, 2006. 46 pp. Available from United Nations Inter-Agency Secretariat of the International Strategy for Disaster Reduction (UN/ISDR), International Environment House II, 7-9 Chemin de Balexert, CH 1219 Chatelaine, Geneva 10, Switzerland http://www.unisdr.org]

The focus of early warning systems should be to warn and inform the citizens and governments of changes on a seamless timescale stretching from minutes for immediate threats requiring urgent evasive action; to weeks for more advanced preparedness; to seasons and decades for climate variations and changes, and to provide a basis for disaster risk reduction and sustainable development (brunet et al., 2010). To-date most of the early-warning systems have been based on weather predictions, which provide short-term warnings often with sufficient lead-time and accuracy to take evasive action. However, the range of actions that can be taken if early warning systems are informed by no other climate information than short-range predictions is limited. Weather predictions often provide less than 24 hours notice of an impending extreme weather event, and options in resource-poor areas may not extend beyond the emergency evacuations of people. Thus although lives may be saved, livelihoods may still be destroyed, especially those of the poorest communities.

Partly because of the rapid growth in the number of humanitarian disasters, the disaster risk management community has become attentive to the risk of possible changes in weather and climate hazards as a result of climate change, in particular regarding changes in floods, droughts, heat waves and storms. Early warning systems provide one possible adaptation option to minimise any deleterious consequences resulting from any projected exacerbation of natural severe extremes. Such systems also provide a mechanism to increase public knowledge and awareness of natural risks, and may foster improved policy and decision making at various levels. Effective tools for weather and seasonal prediction (and early warning) are among the possible approaches to assist in adaptation to possible increases in the occurrence of weather- and climate-related hazards. However, with increasing uncertainty in the predictions at longer timescales, it is imperative that appropriate response strategies be identified to ensure that confidence is retained in the early warning system when anticipated hazards do not manifest. At the longer timescales, the appropriate responses may involve little more than no-regrets actions with forecasts providing one additional factor in the choice between competing priorities given finite resources (Braman et al. 2010; Tall et al. 2010); at the shorter timescales, as confidence in the prediction of specific anticipated hazards increases, more committed actions can be taken with the understanding that there remains some possibility of the hazardous event not occurring.

Examples of Benefits of Early Warning Systems

Predictions of hazardous events can contribute to disaster risk reduction and sustainable development (McBean, 2007; 2009). There are examples in the past of major benefits of early warning systems (Einstein and Sousa 2007). In 1977, a major cyclone resulted in about 20,000 deaths on the east coast of India. In the years that followed, an early warning system was established, complete with meteorological radars and emergency plans, and many lives were saved as a result when the same area was hit again by cyclones of similar strength in 1996, when about 100 deaths occurred, and in 2005, when the death toll was just 27 (UNISDR, 2009). Assessments of adaptive capacity to responding to cyclone warnings have been done for India (Sharma et al., 2009), Florida (Smith and McCarty, 2009), New Orleans (Burnside et al., 2007), New South Wales, Australia (Cretikos et al., 2008) and China (Wang et al., 2008). Predictions of land-fall for tropical cyclones are very important (Davis et al., 2008). As presented in Case Study on Tropical Cyclones, major reductions in loss of life were achieved "*after the devastating cyclone of 1970, the Bangladesh government initiated several structural and non-structural measures to reduce the cyclone risk (Paul, 2009)*". These measures included implementation of an early warning system. One of the issues is providing warnings in order that people can evacuate (Paul and Dutt, 2010; Stein et al., 2010). If forecasts are often incorrect, the response of people is affected (Dow and Cutter, 1998). Public health impacts due to hazards also depend on the preparedness of the local community (Vogt and Guha Sapir, 2009) and this can be assisted by early warnings. However, accurate predictions alone are insufficient for a successful early warning system as is demonstrated by the case in the United Kingdom, a country which regularly experiences flooding. Severe damage and health problems followed flooding in 2007 due to warning communication that was insufficiently clear, issued too late, and inadequately coordinated, so that people, local government and support services were unprepared (UNISDR, 2009). Heat-health warnings have also been effective (Hajat et., 2010; Rubio et al., 2010; Michelozzi et al., 2010; Fouillet et al., 2008) although improvements are still needed. There are also social impacts of warning systems (Kalkstein and Sheridan, 2007)

While most of the successfully implemented early warning systems to date have focused on shorter timescales [for example, for tornadoes (Doswell et al. 1993)], benefits of improved predictions on the sub- to seasonal scales have been reviewed (Nichols 2001; Brunet et al 2010). Since hazardous atmospheric events occur on timescales from minutes for tornadoes, for example, through seasons and decades in terms of the climatically-changing occurrences of extremes (McBean, 2000), and since planning for hazardous events involves decisions across a full range of timescales, *"An Earth-system Prediction Initiative for the 21st Century"* covering all scales has been proposed (Shapiro et al. 2007; 2010). With improvements in numerical weather models (Simmons and Hollingsworth, 2002) and stochastic design (Medina-Cetina and Nadim, 2008), early warning systems based on medium-range and seasonal forecasts for flood hazards across Europe and West Africa have been considered (Bartholmes et al. 2008; Tall et al. 2010).

Similarly, there have been important developments in recent years in the area of subseasonal and seasonal-to-interannual prediction, leading to dramatic improvements in predictions of weather and climate extremes (Nicholls, 2001). Some of these improvements, such as the use of soil moisture initialization for weather and (sub-) seasonal prediction (Koster et al., 2010), have potential for applications in transitional zones between wet and dry climates, and in particular in mid-latitudes (Koster et al., 2004). Such applications may be potentially relevant for projections of temperature extremes and droughts (Schubert et al., 2008; Koster et al., 2010). On decadal and longer timescales, predictions are improving and could form the basis for early-warning systems in the future (Meehl et al., 2007, 2009; Palmer et al, 2008; Shukla et al., 2009, 2010).

Methods for improving predictions remain a very active area of research, and significant further progress may be reached in coming years. However, for such predictions to be of use to end users, improved communication will be required to develop appropriate indices relevant for specific regional impacts. For example predictions of the probability of climate variables such as average temperatures in the format of terciles commonly used in seasonal-to-interannual climate predictions may not be the most relevant information for impacts. A better awareness of such issues in the climate modelling community, from improved interactions with the disaster risk management community (and other user communities), may lead to the development of more useful applications for weather and climate hazard predictions. Such prediction systems, if carefully targeted and of sufficient accuracy, can be a useful tool for reducing the risks related to climate and weather extremes.

<u>What can We Learn from Experience with Subseasonal and Seasonal-to-Interannual Climate Predictions?</u>

Developing resiliency to weather and climate involves developing resiliency to its variability on a continuum of timescales, and in an ideal world early warnings would be available across this continuum. However, investments in developing such resiliency are likely to be primarily informed by information only over the expected lifetime of the investment, especially amongst poorer communities. For example, in deciding what crops to grow next season, while some consideration may be given to longer-term strategies, the more pressing concern is likely to be the expected climate conditions over the next season. Indeed, there is little point in preparing to survive the impacts of possible disasters a century hence, if one is not equipped to survive more immediate threats. Thus, within the disaster risk management community, preparedness for climate change necessarily involves preparedness for climate variability.

Despite this inevitable focus on shorter-term survival and hence interest in warnings of hazards in the near-term, even in this context the longer timescales cannot be ignored if reliable predictions of climate variability are to be made. For example, considerations of changing greenhouse gas concentrations are important even for seasonal forecasting, because including realistic greenhouse gas concentrations can significantly improve forecast skill (Doblas-Reyes et al., 2006; Liniger et al., 2007). Similarly, adaptation tools traditionally based on long-term records (e.g., streamflow measurements over 50-100 years) under the assumption of stationary climate conditions, may create a bias towards obsolete adaptation (e.g., Milly et al., 2008). Thus reliable prediction and successful adaptation are both impossible as long as a myopic perspective on a single timescale, be that climate change, seasonal, or weather scale, is retained.

While there appear to be obvious potential benefits of early warning systems that span a continuum of timescales, for much of the disaster risk management community the idea of preparedness based on predictions is a new concept: the community has largely operated in a reactive mode, either to disasters that have already occurred, or in emergency preparedness for one that is anticipated to occur with high confidence in the immediate future. The possibility of using weather and climate predictions longer than a few days to provide advanced warning of extreme conditions has been only a very recent development. Despite what has been over a decade of operational seasonal predictions in many parts of the globe, examples of the use of such information by the disaster risk management community are limited, for a number of reasons. Not least of these reasons are the large uncertainties in the predictions, and difficulties in understanding their implications. Most seasonal rainfall predictions, for example, are presented in a so-called probabilistic tercile format: probabilities are provided that the total rainfall over the coming few (typically three) months, and averaged over large areas (typically tens of thousands of square kilometres), will be amongst the highest and lowest third of rainfall totals as measured over a historical period. Not only are the probabilities almost invariably lacking in sharpness (highest probabilities are most frequently around 40% or 45%, compared to the climatologically expected probability of 33%), but the target variable of the seasonal rainfall total does not necessarily map well onto flood occurrence. Although higher-than-normal seasonal rainfall will often be associated with a higher risk of floods, it is possible for the seasonal rainfall total to be unusually high but yet for no flooding to occur because of the frequent occurrence of moderately heavy rain. Alternatively, the total may be unusually low, but yet flooding might occur because of the occurrence of an isolated heavy rainfall event (see also chapter 3 for a discussion of these aspects). Thus even when seasonal predictions are understood properly, it may not be obvious how to use them – the uncertainty in the predictions is very high and the predicted variable may not be of immediate relevance. These problems emphasize the need for the development of tools that can translate such information to quantities directly relevant to end users, and thus for better communication between modelling centres and end users. Where targeted applications have been developed, some success has been reported (e.g., for malaria prediction, Thomson et al., 2006; Jones et al., 2007). Nonetheless, there can be additional obstacles such as policy constraints, which may restrict the range of possible actions that could be taken. Technical constraints, such as limited telecommunications infrastructure, can also limit the utility of predictions.

Notwithstanding these obstacles to the use of seasonal predictions in disaster risk management, the successful use of such predictions has been possible, and can be promoted by attending to the obstacles. For example, the large uncertainty in the information, and, to some extent, some of the policy constraints, may be surmountable by identifying no-regrets strategies. While all preparative actions have some direct cost, and so it is impracticable to be always prepared for all possible eventualities, seasonal predictions can help to prioritize amongst a list of actions. A clear instance of taking such action is provided by the International Federation of Red Cross and Red Crescent Societies (IFRC) West and Central Africa Zone (WCAZ) flood preparedness and response during 2008. In response to a set of predictions for the rainfall season for the region issued in May 2008, actions were taken to pre-position relief items, to improve disaster response capacity through trainings, to develop flood contingency plans, and to launch pre-emergency funding requests for preparedness activities and response. Although it is impossible to quantify the benefits of these actions, evidence suggests that lives were saved and the costs of relief reduced (Braman et al., 2010).

Learning and Lessons Identified

Early warning systems directly contribute to climate change adaptation and disaster risk reduction. Early warning systems can increase effectiveness of adaptation strategies and practices by providing information on the type of extreme events that may occur in the near and longer-term futures. This sense of “seeing the future”, including projected risks, anticipatory strategies and actions, is essential towards effectively preparing for, responding to, and recovering from extreme events and disasters require understanding current and projected risks. Effective disaster risk management in a changing climate is facilitated by anticipatory strategies within and between sectors, with strong co-ordination and realizing adaptation potentials requires anticipation of vulnerabilities and anticipatory actions.

It is recognized that vulnerability, exposure and hence risk can never be reduced to zero, but it can be reduced and managed but effective early warning systems on short and longer timescales will convince disaster risk managers on appropriate actions. By incorporating longer-term early warning systems into disaster risk management, improved current risk management can facilitate adaptation to climate change. It is important to recognize that managing the rising uncertainty of a changing climate requires anticipatory action and early warning systems can contribute to that and climate-smart disaster risk management.

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9.3. Synthesis of Lessons Identified from Case Studies

This chapter examined case studies of extreme climate events, vulnerable regions and methodological-management approaches in order to glean lessons and good practices. This is an important role because it adds context and value to this whole report. The role of case studies is to contribute a more focused analysis which conveys the reality of the event: the extent of human loss and financial damage; the response strategies and their successes and failures; prevention measures and their effect on the overall event; and even cultural or region-specific factors that may influence the outcome. Most importantly, case studies provide a medium through which to learn practical lessons about success in disaster risk reduction and climate change adaptation. These will prove useful as states and people try to adapt to a changing climate.

In the case studies several recurring themes and lessons occurred and they should be highlighted for use by policymakers. One lesson is to invest in knowledge. In the case studies that dealt with cyclones, floods and droughts, as examples of extreme events, a common factor was the need for greater amounts of information on threats before the events occur incliding early warnings. Clearer understanding of health impacts and the benefits of safer hospitals and health care facilities are another important issue. In all cases, the point was made that with greater information available it would be possible to know the risks better and ensure that response strategies were adequate to face the coming threat. Research is required to improve our knowledge and it needs to include an integration of natural, social, health and engineering science and their applications.

Disaster risk reduction (DRR) and climate change adaptation (CCA) are mutually reinforcing and similar directions in measures are needed. Where there is uncertainty as to the details of climate change in the future, this uncertainty can be reduced, in a sense, through the risk reduction approaches of DRR. A greater investment in proactive hazard and vulnerability reduction measures, as well as development of systemic and programmatic capacities to respond and recover from the events is needed, hence a risk management approach.

Another lesson is that, in order to implement a successful DRR or CCA strategy, legal and regulatory frameworks are beneficial in ensuring direction, coordination and effective use of funds. The case studies are helpful in this endeavour as effective implemented legislation has created a framework for governance of disaster risks. While this type of suggestion is mainly for national governments and how they devolve to local administrations, it holds an important message for international governance and institutions as well. Here, cooperating with other countries to attain better analysis of the threat, it is possible to establish frameworks that will allow institutions to change their focus with the changing threat, therefore maintain their usefulness. This cooperation could be at the local level through to national to international levels. Here and in other ways, civil society has an important role.

Repeatedly throughout the chapter, reference was made to ‘smart investment’ with regard to risk management measures. The idea overall was that it is better to invest in preventative and adaptation based tools than in the response to extreme events. This includes the need to invest in primary to higher education and research and monitoring. The reasoning behind such statements was that if the disaster has already occurred, the damage has been done. The main goal of both disaster risk reduction and climate change adaptation is to reduce the risk and vulnerability of people and property. In other words, measures exist that could be taken to reduce the damage that is inflicted as a result of extreme events. The values in investment in increasing knowledge and warning systems, adaptation techniques and tools and preventative measures will cost money now, but may save money and lives in the future.

Table 9-1: Affected people and fatalities caused by tropical cyclones Bhola (1970), Gorky (1991), and Sidr (2007) in Bangladesh.

Cyclone event	Storm Surge	Maximum Wind Speed	Number of Affected Districts	Number of Affected People (approximate)	Mortality (approx.)
Bhola (1970)	6-9 m	223 km/h	5	1 mill.	300,000 – 500,000
Gorky (1991)	6-7.5 m	225 km/h	19	14 mill.	138,000
Sidr (2007)	5-6 m	Up to 245 km/h	30	8-10 mill.	4,200

Sources: Paul 2009, GoB 2008, Karim and Mimura 2008, CRED 2009.

Table 9-2: Improvements in key measures for reducing risk of tropical cyclones in Bangladesh since 1970.

Cyclone event	Cyclone shelters (Number)	CPP Volunteers	Cyclone Warning System	Population evacuated
Bhola (1970)	Nil	Nil	No warning capacity*	Nil
Gorky (1991)	512	20,000	Limited capacity	350,000
Sidr (2007)	3,976	43,000	Storm Warning Centre equipped with modern technology and access to mobile phones in coastal regions.	1,500,000

Source: GoB 2008, ISDR 2009, Sommer and Mosley 1972,Paul 2009.
*(*Forecast was issued by Indian Meteorological authority and communicated to Cox's bazaar in the evening before land fall of Bhola Cyclone. Reliable information is not available)*

Table 9-3: Characteristics of tropical cyclone Nargis (2008) in Myanmar.

Parameter	**Nargis 2008 (Myanmar)**
Max. wind speed	235 km/h
Storm surge	~4 m
Reported fatalities	138,000
People Exposed/Affected	2-8 millions

Sources: Webster 2008, PREVIEW 2009, CRED 2009.

Table 9-4: Example of adaptation options (Masahiro, 2008).

Climate change adaptation				
Climate change increases hazards	**Measures to Reduce Exposure**	**Measures to Reduce Vulnerability**	**Measures to Strengthened Capacity**	**Risk reduction**
Hydro-meteorological hazards increase Increases are expected in the variability and intensity of tropical cyclones, thunderstorms, hailstorms, tornados, blizzards, heavy snowfall, avalanches, coastal storm surges, floods (including flash floods), drought, heatwaves and cold spells. Hydro-meteorological conditions also can be a factor in other hazards such as landslides, wildland fires, locust plagues, epidemics, and in the transport and dispersal of toxic substances and volcanic eruption material. [a/]	**Retreat** 1. Retire and move critical infrastructure or housing that are in locations that become too hazardous **Restore natural buffers** 2. Mangroves buffer storm surge 3. Wetlands attenuate flood peaks 4. Reforestation retards runoff 5. Enhance infiltration in urban areas **Protect** • Flood embankments, polders, and sea walls, frequently combined with pumped drainage. • Increasing the hydraulic efficiency of the flood channel with dredging, widening and removal of obstructions; • Diverting the flood flows around the city through diversion channels; • Attenuating the flood flows upstream with reservoirs or through the managed flooding of the agricultural and wetland.	**Accommodate** • Flood proofing building exteriors • Placing lowest habitable or operable level of a house, building or factory above extreme flood elevation • Establishing cropping calendars and seed types that reflect flood/drought frequencies • Ensure critical public facilities are accessible and functional during floods/disasters • Major transport networks need to have elevations above extreme flood elevations • Power lines and transformers need to be above flood levels and high enough to allow clearance for rescue boats • Insulation of air-conditioned buildings lowers power costs and reduces GHG emissions	**Improved management** • Early warning systems • Land use planning and zoning • Building codes • Enforcement systems codes and zoning measures • Hazard mapping and public awareness campaigns • Review reservoir operation rules • Conduct dam safety assessments (including review of PMF) **Build resilience** • Community based disaster risk management plans and exercises • Evacuation plans and shelters • Meteorological forecasts	**Adaptation measures reduce risks/losses** • Climate change increases variability and intensity of hydro-meteorological hazards which increases risk • Risks are reduced when exposure and vulnerability are reduced, or if capacity is increased. • Climate change mitigation efforts reduce potential hazards and therefore risks.
	Structural measures: Any physical construction to reduce or avoid possible impacts of hazards, or application of engineering techniques to achieve hazard resistance and resilience in structures or systems. [a/]		**Non-structural measures:** Any measure not involving physical construction that uses knowledge, practice or agreement to reduce risks and impacts, in particular through policies and laws, public awareness raising, training and education. [a/]	

Table 9-5: Examples of mechanisms for managing risks at different scales.

	Local *Households, SMEs, farms*	***National*** *Governments*	***International*** *Development organizations, donors, NGOs, …*
Non-insurance mechanisms			
Solidarity	Help from neighbors and local organizations	Government post/disaster assistance; government guarantees/bail outs	Bi-lateral and multi-lateral assistance, regional solidarity funds
Informal risk sharing	Kinship and other mutual arrangements	Government diversions from other budgeted programs	Remittances
Savings and credit (inter-temporal risk spreading)	Savings; micro-savings; fungible assets; food storage; money lenders; micro-credit	National reserve funds; domestic bonds	Regional pools, post-disaster credit; contingent credit; emergency liquidity funds
Insurance mechanisms			
Insurance instruments (risk transfer and pooling)	Property insurance; micro-insurance; crop and livestock insurance; weather hedges	National insurance programs; sovereign risk transfer	Re-insurance; regional catastrophe insurance pools
Alternative risk transfer			Catastrophe bonds; risk swaps, options, and loss warranties

Source: Linnerooth-Bayer and Mechler, 2009

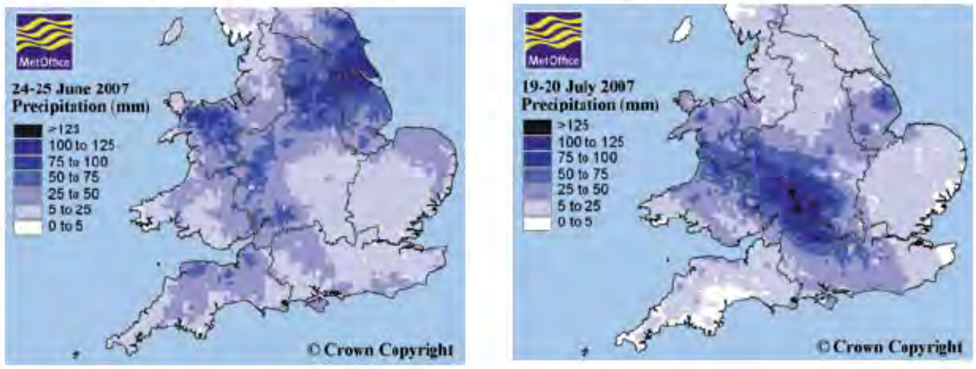

Figure 9-1: Precipitation levels for England and Wales during 24-25 June and 19-20 July 2007.

Figure 9-2: Canada’s Permafrost Zones (NRTEE, 2009).

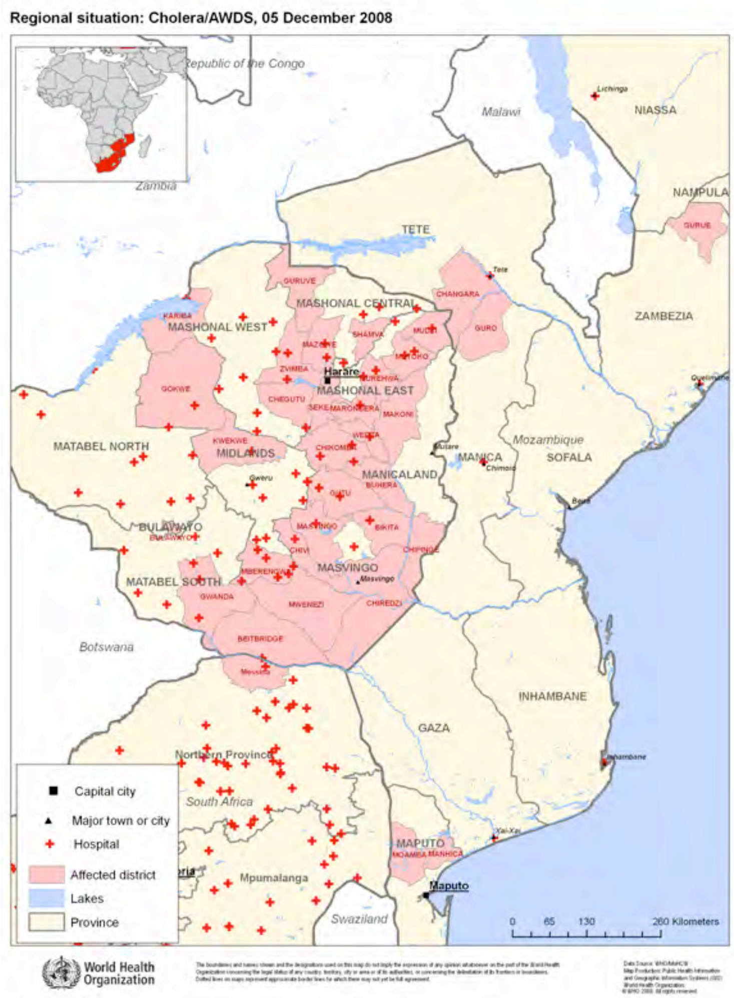

Figure 9-3: Regional spread of the 2008 Zimbabwe epidemic

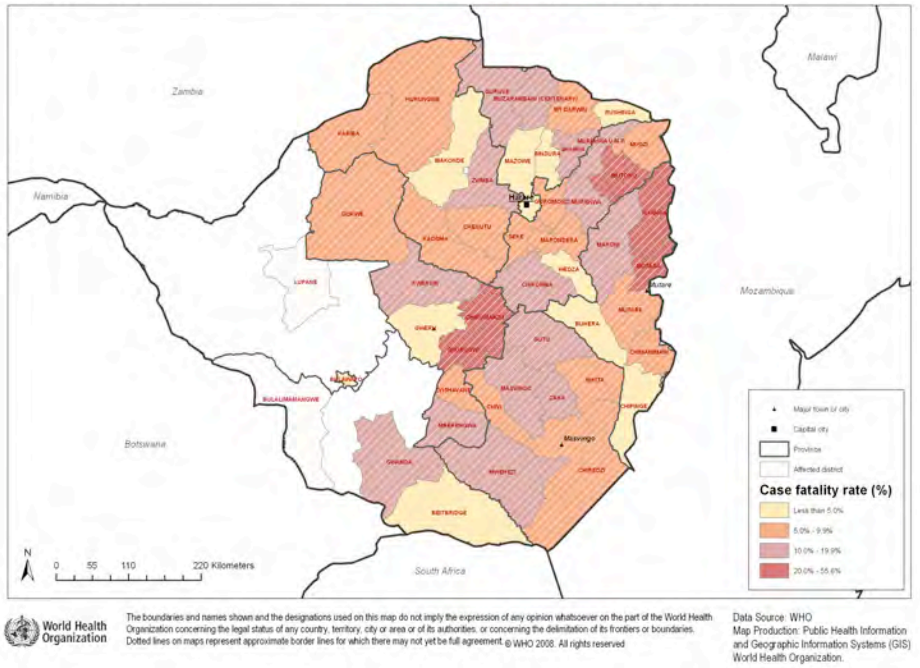

Figure 9-4.Case fatality rates for Zimbabwe by district