

PART

1



Reducing Human Vulnerability: Helping People Help Themselves

Families in Bangladesh are deciding whether to rebuild their homes and livelihoods after yet another flood—once occasional, now every few years—or to take their chances in Dhaka, the crowded capital. In the tall forests of southern Australia, families are deciding whether to rebuild their homes after the most damaging fires in history—aware that they are still in the grip of the longest and most severe drought on record. With losses from extreme climate events inevitable, societies have explicitly or implicitly chosen the risk they bear and the coping strategies to deal with them. Some losses are so high and the coping so insufficient that development is impeded. As the climate changes, more and more people risk falling into what is called the “adaptation deficit.”

Reducing vulnerability and increasing resilience to the climate has traditionally been the responsibility of households and communities¹ through their livelihood

choices, asset allocations, and locational preferences. Experience shows that local decision making, diversity, and social learning are key features of flexible, resilient communities² and that vulnerable communities can be effective agents of innovation and adaptation.³ But climate change threatens to overwhelm local efforts, requiring more from national and global supporting structures.

People’s vulnerability is not static, and the effects of climate change will amplify many forms of human vulnerability. Crowded cities expand into hazardous zones. Natural systems are transformed through modern agriculture. Infrastructure development—dams and roads—create new opportunities but can also create new risks for people. Climate change, superimposed on these processes, brings additional stress for natural, human, and social systems. People’s livelihoods need to function under conditions that will almost certainly change but cannot be predicted with certainty.

Whichever mitigation pathway is followed, the temperature and other climate changes over the next decades will be very similar. Temperatures are already about 1°C above those of the preindustrial era, and all realistic mitigation scenarios suggest that we may expect another 1°C by midcentury. The world of 2050 and beyond, however, will be much different from today’s—just how different depends on mitigation. Consider two possibilities for this generation’s children and grandchildren. In the first scenario the world is on track to limiting

Key messages

Further climate change is unavoidable. It will stress people physically and economically, particularly in poor countries. Adapting requires robust decision making—planning over a long time horizon and considering a broad range of climate and socioeconomic scenarios. Countries can reduce physical and financial risks associated with variable and extreme weather. They can also protect the most vulnerable. Some established practices will have to be expanded—such as insurance and social protection—and others will have to be done differently—such as urban and infrastructure planning. These adaptation actions would have benefits even without climate change. Promising initiatives are emerging, but applying them on the necessary scale will require money, effort, ingenuity, and information.

temperature increases to 2–2.5°C above preindustrial levels. In the second the emissions are much higher, leading eventually to temperatures about 5°C or more above preindustrial levels.⁴

Even on the lower temperature trajectory many ecosystems will come under increasing stress, patterns of pests and disease will continue to change, and agriculture will require significant changes in practice or displacement in location. On the higher temperature trajectory most of the negative trends will be even worse, and the few positive trends, such as increases in agricultural productivity in cooler cropping regions, will be reversed. Agriculture will undergo transformational change in practices and locations. Storm intensity will be higher. And sea levels are likely to rise by about one meter.⁵ Floods, droughts, and extreme temperatures will be much more common.⁶ The past decade has been the hottest on record, but by 2070 even the coolest years are likely to be hotter than now. As the physical and biological stresses arising from climate change increase, so will social tension.

On the higher trajectory, warming could trigger feedbacks in Earth systems that would make it difficult to further constrain temperature increases, regardless of mitigation. These feedbacks could rapidly collapse ecosystems, as some are predicting for the Amazon and the boreal peat lands (see focus A). People in that higher-track world would see rapidly accelerating losses and costs reverberate through their societies and economies—requiring adaptation at a scale unprecedented in human history. International tensions could be expected to rise over resources, and migration away from the areas most affected would increase.⁷

On the lower track, adaptation will be challenging and costly, and business-as-usual development will be far from sufficient. Broader and accelerated implementation of policies that have proved successful is paramount as is adaptation that harnesses the ingenuity of people, institutions, and markets. On the higher track the question is whether warming may be approaching, or already exceeding, levels to which we can adapt.⁸ Some argue

convincingly that ethics, culture, knowledge, and attitudes toward risk limit human adaptation more than physical, biological, or economic thresholds.⁹ The adaptation effort that will be required by future generations is thus determined by how effectively climate change is mitigated.

Incremental environmental impacts imply stronger physical constraints on future development. Climate-smart policies will have to address the challenges of a riskier and more complex environment. Development practice has to be more adaptive to shifting baselines, grounded in strategies robust to imperfect knowledge.¹⁰ Cropping strategies need to be robust under more volatile weather conditions by seeking to maintain long-term consistency in output rather than to maximize production. Urban planners in coastal cities need to anticipate demographic developments and new risks from rising seas or flooding. Public health workers need to prepare for surprising changes in climate-linked disease patterns.¹¹ Information is crucial to support risk-based planning and strategies—it is the basis of good policy and better risk management.

Managing ecosystems and their services will be more important and more difficult. Well-managed landscapes can modulate flood waters. Intact coastal wetlands can buffer against storm damage. But management of natural resources will face a rapidly changing climate with more extreme events and with ecosystems under increasing threats from stresses other than climate (such as land-use and demographic change).¹² Managing such physical risks is an integral part of climate-smart development—an essential step to avoid avoidable impacts on people.

However, not all physical impacts are avoidable, particularly those linked to extreme and catastrophic events whose probability is difficult to assess under climate change. Eliminating the risk of the most extreme events is not possible, and attempting to do so would be extremely costly given the uncertainty about the location and timing of impacts. Being financially prepared to cope with climate impacts is critical for both households and

government. This requires flexible risk-spreading mechanisms.

As chapter 1 discusses, the poor have the least capacity to manage physical and financial risk and to make longer-term adaptation decisions. Their lives are affected more by climate, whether they practice subsistence farming or are landless squatters in a floodplain at the urban fringe. Other social groups share many of the vulnerabilities of the poor stemming from their lack of entitlements, productive assets, and voice.¹³ Social policy, a critical complement to physical and financial risk management, provides many tools to help manage the risk affecting the most vulnerable and to empower communities to become agents in climate-change management.

This chapter focuses on measures that will assist people in handling today's variable climate and the climate changes that occur over the next few decades. It first describes a policy framework based on strategies that are robust to climate uncertainty and management practices that are adaptive in the face of dynamic conditions. It then looks at managing physical risks, financial risks, and social risks.

Adaptive management: Living with change

Climate change adds an additional source of unknowns for decision makers to manage. Real-world decision makers make decisions under uncertainty every day, even in the absence of climate change. Manufacturers invest in flexible production facilities that can be profitable across a range of production volumes to compensate for unpredictable demand. Military commanders insist on overwhelming numerical superiority. Financial investors protect themselves against fluctuations in markets by diversifying. All these forms of hedging are likely to lead to suboptimal results for any fixed expectation about the future, but they are robust in the face of uncertainty.¹⁴

A compounding set of uncertainties—about demographics, technology, markets, and climate—requires policies and investment decisions to be based on imperfect and incomplete knowledge. Local and national decision makers face even greater

uncertainties because projections tend to lose precision at finer scales—an inherent problem of downscaling from coarse, aggregate models. If decision parameters cannot be observed and measured,¹⁵ robust strategies (see chapter 1) that directly address the reality of a world of shifting baselines and intermittent disturbances¹⁶ are the appropriate framework in a context of unknown probabilities.

Accepting uncertainty as inherent to the climate change problem and robustness as a decision criterion implies changing decision-making strategies for long-lived investment and long-term planning. It demands rethinking traditional approaches that assume a deterministic model of the world in which the future is predictable.

First, priority should be given to no-regrets options: investment and policy options that provide benefits even without climate change. Such options exist in almost every domain—in water and land management (see chapter 3), in sanitation to reduce water-borne diseases (controlling sewer leakage), in disaster risk reduction (avoiding high-risk zones), in social protection (providing assistance to the poor). But such options often are not implemented, partly because of a lack of information and transaction costs but also because of cognitive and political failures (see chapter 8).¹⁷

Second, buying “safety margins” in new investments can increase climate resilience, often at low cost. For instance, the marginal cost of building a higher dam or including additional groups in a social protection scheme can be small.¹⁸ Safety margins account not only for possible impacts of climate change (more severe events) but also for the uncertainty in socioeconomic development (changes in demand).

Third, reversible and flexible options need to be favored, accepting that decisions can be wrong and thus keeping the cost of reversing them as low as possible. Restrictive urban planning because of uncertain flooding outcomes can be reversed more easily and cheaply than future retreat or protection options. Insurance provides flexible ways of managing risk and protecting necessary investment when the direction and magnitude of change are uncertain.¹⁹

Farmers transitioning to drought-tolerant varieties (rather than investing in irrigation) can use insurance to protect their seasonal investment in new seeds from an exceptionally severe drought. For storm-prone areas a combination of early warning systems, evacuation plans, and (possibly expensive) property insurance can provide more flexibility to save lives and replace homes than can protecting entire coastal areas with infrastructure or depopulating them unnecessarily.²⁰

Fourth, institutionalizing long-term planning requires forward-looking scenario analysis and an assessment of strategies under a wide range of possible futures. This leads to periodic reviews of investment (and, if necessary, revisions), and it improves policies and practices by iterative learning from outcomes. Widening the spatial scope of planning is equally critical to be prepared for changes that may propagate over longer distances, such as the melting of glaciers that change the water supply of urban zones hundreds of kilometers downstream, widespread droughts that affect regional grain markets, or accelerated rural-urban migration caused by environmental degradation. But the required structural changes can be difficult because of the inertia in prevailing management practices.²¹

Implementing such strategies through adaptive management entails continuous information development, flexible and robust planning and design, participatory implementation, and monitoring and evaluation of feedback. It realigns decisions and management with the scale of ecological and social contexts and processes, such as watersheds and ecoregions, and can be driven by local or community management systems.²² It stresses management informed by scientific and local knowledge, as well as policy experiments that develop understanding, set learning as an objective, and improve the ability to make decisions under uncertainty (box 2.1).²³

Involving stakeholders in planning increases ownership and the likelihood that actions will be sustained.²⁴ Boston and London both have climate-change strategies. In Boston the process was research-led, with inconsistent stakeholder engagement. The completed study, seen as overly technical, has had little impact. London used a bottom-up approach, engaging many stakeholders. And after the London Warming Report was released, the Climate Change Partnership evolved from the stakeholder organization to continue adaptation planning.²⁵

A risk-based decision-making model favoring robustness and longer-term planning, and appropriate local, community, and national governance structures is essential for adaptation to climate change.²⁶ Increasing pressure on scarce resources (land, water), combined with major socio-demographic transformations (population growth, urbanization, globalization) and a shifting climate, provide much less room to leave risks unmanaged. A storm hitting a modern, rapidly growing coastal city has the potential to cause a lot more damage than in the past when the coast was less populated and built up. In the face of the uncertainty arising from climate change, robust strategies and adaptive management provide the appropriate framework to better manage physical, financial, and social risks.

BOX 2.1 *Characteristics of adaptive management*

Adaptive management is an approach to guide intervention in the face of uncertainty. The principal idea is that management actions are informed by explicit learning from policy experiments and the use of new scientific information and technical knowledge to improve understanding, inform future decisions, monitor the outcome of interventions, and develop new practices. This framework establishes mechanisms to evaluate alternative scenarios and structural and nonstructural measures, understand and challenge assumptions, and explicitly consider uncertainties. Adaptive management has a long time horizon for

planning and capacity building, and is aligned with ecological processes at appropriate spatial scale. It creates an enabling framework for cooperation between administrative levels, sectors, and line departments; broad stakeholder participation (including research centers and non-government organizations) in problem solving and decisionmaking; and adaptable legislation to support local action and respond to new information.

Sources: Adapted from Raadgever and others 2008; Olsson, Folke, and Berkes 2004.

Managing physical risks: Avoiding the avoidable

Natural systems, when well managed, can reduce human vulnerability to climate risks

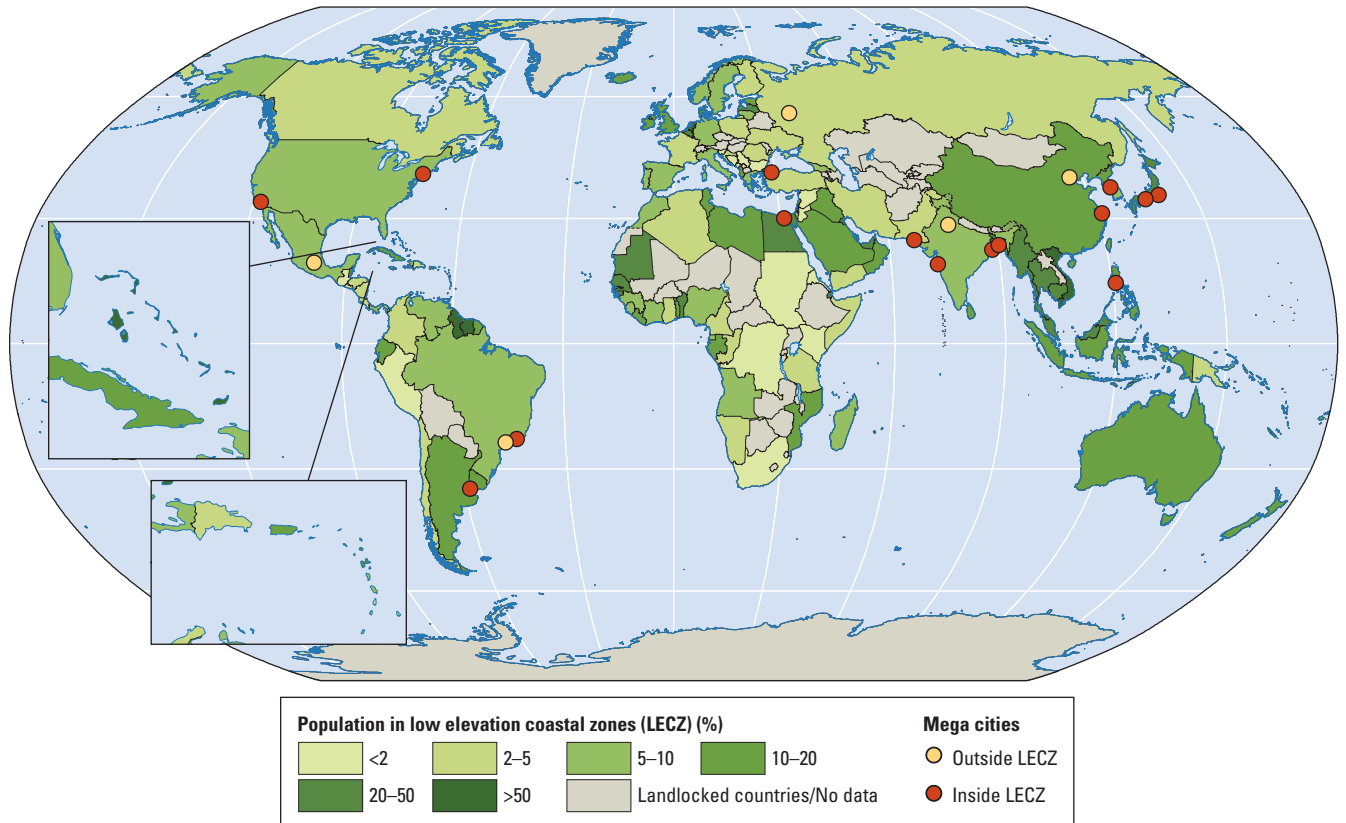
and deliver developmental co-benefits, reduce poverty, conserve biodiversity, and sequester carbon. Ecosystem-based adaptation—maintaining or restoring natural ecosystems to reduce human vulnerability—is a cost-effective approach to reducing climate risks and one that offers multiple benefits (see focus B). For example, forested catchments buffer water flows from moderate rains far better than nonforested catchments, but heavier rains quickly saturate the sponge, so most water moves quickly over the land.²⁷ Well-vegetated wetlands downstream may be needed to further buffer water flows while natural drainage systems carry it away. But wetlands converted to agriculture or urban settlements and simplified drainage systems inevitably fail, leading to flooding. A comprehensive response to flood management includes maintaining catchment cover, managing wetlands and river channels, and siting

infrastructure and planning urban expansion appropriately. Similarly, coastal mangrove forests protect against storm surges partly by absorbing the flows and partly by keeping human settlements behind the mangroves farther from the sea.

Build climate-smart cities

Half the world’s people now live in cities, a share that will rise to 70 percent by 2050.²⁸ Of urban population growth (5 million new residents a month), 95 percent will be in the developing world, with small cities growing fastest.²⁹ Urban areas concentrate people and economic assets, often in hazard-prone areas as cities have historically prospered in coastal areas and at the confluence of rivers. In fact, low-elevation coastal zones at risk from rising sea levels and coastal surges are home to about 600 million people globally and 15 of the world’s 20 megacities (map 2.1).³⁰

Map 2.1 At risk: Population and megacities concentrate in low-elevation coastal zones threatened by sea level rise and storm surges



Source: United Nations 2008a.

Note: Megacities in 2007 included Beijing, Bombay, Buenos Aires, Cairo, Calcutta, Dhaka, Istanbul, Karachi, Los Angeles, Manila, Mexico City, Moscow, New Delhi, New York, Osaka, Rio de Janeiro, São Paulo, Seoul, Shanghai, and Tokyo. Megacities are defined as urban areas with more than 10 million inhabitants.

Climate change is only one of many factors that determine urban vulnerability. For many coastal cities, migration increases the population exposed to rising sea levels, storm surges, and floods,³¹ as in Shanghai, where the net annual influx of people exceeds the natural growth rate by a factor of four.³² And many cities in river deltas are sinking as a result of groundwater extraction and declining sediment deposits caused by dams upstream. While subsidizing land has been an issue for some time in many coastal cities (New Orleans, Shanghai), it is an emerging threat for Hanoi, Jakarta, and Manila.³³ Urban development farther inland increases the water demand upstream, and many rivers, including the Nile, no longer reach their delta.

Urbanization, done well, can increase resilience to climate-related risks. Higher population densities lower the per capita costs of providing piped treated water, sewer systems, waste collection, and most other infrastructure and public amenities. Sound urban planning restricts development in flood-prone areas and provides critical access to services. Infrastructure developments (embankments or levees) can provide physical protection for many and will require additional safety margins where climate change increases risk. And well-established communication, transport, and early warning systems help evacuate people swiftly, as is the case in Cuba, where up to 800,000 people are routinely evacuated within 48 hours when hurricanes approach.³⁴ Such measures can increase the ability of urban dwellers to cope with shocks in the short term and adapt to a changing climate in the long term.³⁵

Cities are dynamic and highly adaptive systems that offer a wide range of creative solutions to environmental challenges. A number of countries are looking into new urban development strategies that aim at spreading regional prosperity. The Republic of Korea has embarked on an ambitious program to develop “Innovation Cities” as a way to decentralize the country’s economic activities.³⁶ Many of these efforts focus on technological innovation and offer new opportunities to redesign future cities to deal with the climate-change challenges.

Attempts to influence the spatial patterns of urban areas through public policy

interventions show mixed results, however. The Arab Republic of Egypt’s attempt to create satellite cities to decongest Cairo never attracted the projected population and did little to stop population growth in Cairo, partly because of the lack of policies to promote regional integration.³⁷ Successful policies facilitate concentration and migration during the early stages of urbanization and interurban connectivity during the later stages. Public investments in infrastructure are most effective when they increase social equity (through broader access to services) and integrate the urban space (through the transport system).³⁸

Urbanization seldom is harmonious, generating pollution and pockets of wrenching poverty and social dislocation. Today, urban areas in developing countries are home to 746 million people living below the poverty line (a quarter of the world’s poor),³⁹ and the urban poor suffer from more than low income and consumption. Overcrowding, insecure tenure, illegal settlements sited in landslide- and flood-prone areas, poor sanitation, unsafe housing, inadequate nutrition, and poor health exacerbate the vulnerabilities of the 810 million people in urban slums.⁴⁰

These many vulnerabilities call for comprehensive improvements in urban planning and development. Government agencies, particularly local ones, can shape the adaptive capacity of households and businesses (box 2.2). But action by community-based and nongovernmental organizations (NGOs) is also crucial, particularly those that build homes and directly provide services, as slum-dweller organizations do.⁴¹ Sound planning and regulation can identify high-risk zones in urban areas and allow low-income groups to find safe and affordable housing, as in Ilo, Peru, where local authorities safely accommodated a fivefold increase in the population after 1960.⁴² But hard investments in infrastructure may also be required to protect urban zones, such as coastal cities in North Africa, with seawalls and embankments (box 2.3).

A major risk for urban areas is flooding—often caused by buildings, infrastructure, and paved areas that prevent infiltration, exacerbated by overwhelmed drainage systems. In well-managed cities flooding is

BOX 2.2 *Planning for greener and safer cities: The case of Curitiba*

Despite a sevenfold population increase between 1950 and 1990, Curitiba, Brazil, has proven itself to be a clean and efficient city, thanks to good governance and social cooperation. The cornerstone of Curitiba's success lies in its innovative Plano Diretor, adopted in 1968 and implemented by the Instituto de Pesquisa Planejamento Urbano de Curitiba (IPPUC). Rather than use high-tech solutions for urban infrastructure, like subways and expensive mechanical garbage separation plants, the IPPUC pursued appropriate technology that is effective both in cost and application.

Land use and mobility were planned in an integrated fashion, and the city's radial (or axial) layout was designed to divert traffic from the downtown area (three-fourths of the city's people use a highly efficient bus system). The industrial center is built close to the city center to minimize the commute for workers. Numerous natural preservation areas are situated around the industrial area to buffer flooding.

Another part of the city's success is its waste management; 90 percent of its residents recycle at least two-thirds of their

trash. In low-income areas where conventional waste management is difficult, the "Garbage Purchase" program exchanges garbage for bus tokens, surplus food, and school notebooks.

Replications are under way. In Juarez, Mexico, for example, the Municipal Planning Institute is building new homes and transforming the previously inhabited flood zone into a city park.

Source: Roman 2008.

rarely a problem because surface drainage is built into the urban fabric to accommodate floodwaters from extreme events that exceed the capacity of protective infrastructure (see box 2.3). Inadequate solid waste management and drain maintenance, by contrast, can quickly clog drainage channels and cause local flooding with even light rainfall; in Georgetown, Guyana, such a situation led to 29 local floods between 1990 and 1996.⁴³

Cities also have to look beyond their borders to prepare for climate change.

Many Andean cities are reengineering their water supplies to accommodate the shrinking and eventual disappearance of glaciers. Melting means that dry-season water supply is no longer reliable, and reservoirs will need to compensate for the lost water storage and regulation function of glaciers.⁴⁴ In the deltas in Southeast Asia, the rapidly spreading suburbs of cities such as Bangkok and Ho Chi Minh City are encroaching on rice fields, reducing water retention capacity and increasing

BOX 2.3 *Adapting to climate change: Alexandria, Casablanca, and Tunis*

Alexandria, Casablanca, and Tunis, each with 3 million to 5 million people, are assessing the extent of the projected impacts of climate change and devising adaptation scenarios for 2030 through an ongoing regional study. The cities' early responses to their increasing vulnerability show uneven paths toward adaptation.

In Alexandria the recent construction of the corniche, a major six-lane highway built right on the coast, has worsened coastal erosion and steepened the profile of the seabed, causing storm surges to reach farther into the city. Sea defenses are being built without sufficient engineering studies or coordination among the responsible institutions. A lake near the city, a natural receptacle for drainage waters, is suffering acute pollution and real-estate pressures to reclaim it for construction purposes.

Casablanca responded to recent devastating urban flooding episodes with

works to improve upstream watershed management and to broaden the main drainage canals. Leaks in the household water distribution network have been repaired, with the water saving equal to the consumption of about 800,000 people. But coastal zone management remains a concern, given the limited tools to control construction and reduce sand extraction from beaches.

Tunis is also addressing its urban flooding risks by improving drainage canals and controlling informal construction around some natural reservoirs. Sea-walls are being built to defend the most threatened coastal neighborhoods, and the new master plan directs urban development away from the sea. But the city center, already below sea level, is subsidizing, and harbor and logistic facilities, as well as power-generation and water-treatment plants, are under threat. Major

urban redevelopment projects, if carried out, also risk increasing the city's vulnerability to rising seas.

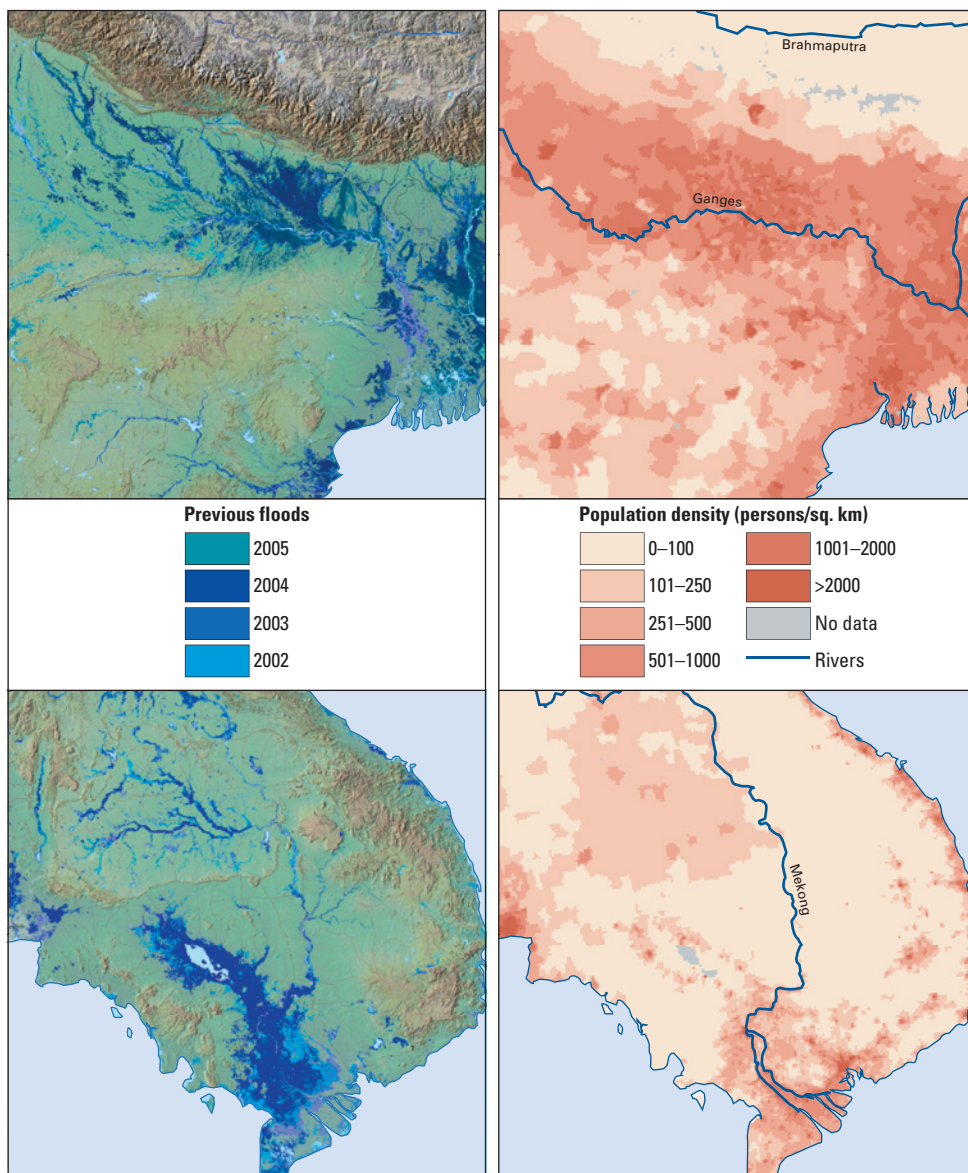
Adaptation to climate change in Alexandria, Casablanca, and Tunis should occur primarily through improving urban planning; identifying land-use and expansion scenarios that would minimize vulnerability; addressing the vulnerability of key infrastructure assets, such as ports, roads, bridges, and water-treatment plants; and improving the capacity of responsible institutions to coordinate responses and manage emergencies. In addition, energy efficiency in buildings and municipal systems can be consistent with increasing resilience to climate change while reducing greenhouse gas emissions.

Source: Bigio 2008.

the risk of floods.⁴⁵ The risk can get worse when upstream storage areas reach their capacity and have to discharge water. Peak river discharges in South and Southeast Asian river basins are projected to increase with climate change, requiring greater upstream efforts to protect urban centers downstream (map 2.2).⁴⁶

Local city governments can promote risk reduction and risk-based planning. Creating a risk information database, developed jointly with citizens, businesses, and officials, is the first step in setting priorities for intervention and identifying hotspots. And establishing a city mandate through executive orders and council legislation can

Map 2.2 A complex challenge: managing urban growth and flood risk in a changing climate in South and Southeast Asia



Sources: WDR team analysis. Flood data: Dartmouth Flood Observatory 2009. Population data: CIESIN 2005.
Note: Living with floods is engrained in the economic activities and culture of people in South and Southeast Asia. The floodplains of some of the major river basins (Ganges, top; Mekong, bottom) concentrate a large number of people and expose agriculture and growing urban centers to seasonal flood risk. Climate change is likely to bring more intense flooding, partly caused by the melting of glaciers in the upper catchment of the Himalaya region and partly by the shorter and more intense monsoon rains, which will likely change flood patterns in the region. At the same time urban centers are rapidly encroaching into agricultural areas that serve as natural retention zones for flood waters, bringing new complexity to managing flood water and urban expansion in the future.

facilitate mainstreaming, as in storm- and flood-prone Makati City, Philippines, where the Disaster Coordination Council plans the city's disaster risk management.⁴⁷

Many municipal actions to promote local development and resilience to extreme events and disasters overlap with the measures for adaptation, including water supply and sanitation, drainage, prevention-focused health care, and disaster preparedness (box 2.4). Such interventions are likely to be in the immediate interest of decision makers in urban contexts (see chapter 8).⁴⁸ It is evidently easier to cast adaptation-oriented initiatives as being in the city's immediate interests, in order to break political logjams for climate action.⁴⁹

Building climate-smart cities will involve considerable use of emerging technologies. However, much of the available technical expertise in developing countries is concentrated in the central government, with local authorities often left to draw from a small pool of expertise.⁵⁰ Urban universities can play a key role in supporting efforts by cities to adopt and implement climate-smart practices through changes in curriculum and teaching methods that enable students to spend more time in the practical world solving local problems.

Keep people healthy

Diseases linked to climate, namely malnutrition, diarrheal diseases, and vector-borne illnesses (especially malaria), already represent a huge health burden in some regions,

particularly Africa and South Asia. Climate change will increase that burden and will be most consequential for the poor (see chapter 1).⁵¹ The estimated additional 150,000 deaths a year attributable to climate change in recent decades may be just the tip of the iceberg.⁵² The indirect effects of climate change mediated by water and sanitation, ecosystems, food production, and human habitation could be far higher. Children are especially susceptible, with malnutrition and infectious diseases (mostly diarrheal diseases) part of a vicious cycle causing cognitive and learning disabilities that permanently affect future productivity. In Ghana and Pakistan the costs associated with malnutrition and diarrheal diseases are estimated to be as high as 9 percent of gross domestic product (GDP) when accounting for long-term productivity losses in later years. These costs will only increase with climate change, if adaptation to these conditions is slow.⁵³

The recent heat waves, such as the one that killed about 70,000 people in Europe in 2003, showed that even high-income countries can be vulnerable.⁵⁴ Heat waves are likely to increase in frequency and intensity (map 2.3),⁵⁵ with urban heat islands producing temperatures up to 3.5–4.5°C higher than in surrounding rural areas.⁵⁶ For better preparedness several countries and metropolitan areas now have heat-health warning systems (box 2.5).

Vector-borne diseases are increasing their geographic spread and are reappearing

BOX 2.4 *Fostering synergies between mitigation and adaptation*

The spatial organization of cities, or their urban form, determines energy use and efficiency. The concentration of population and consumption tends to increase rapidly during the early stage of urbanization and development. Denser urban areas have higher energy efficiency and shorter travel distances (see chapter 4, box 4.7). But increasing the density of people, economic activity, and infrastructure tends to amplify the effects of climate on cities. For instance, green space can reduce the urban heat-island effects, but it can also fall victim to building

developments. Similarly, increased density combined with the paving of infiltration areas hampers urban drainage that mitigates flooding.

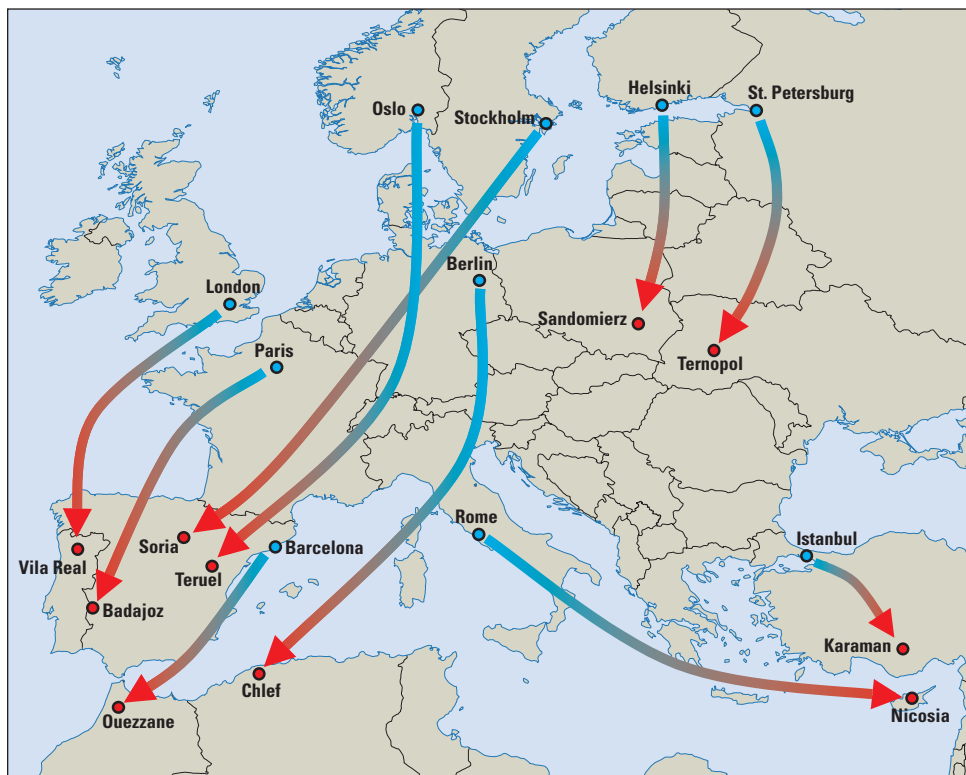
Climate-smart urban design can foster synergies between mitigation and adaptation. Promoting renewable energy sources tends to favor the decentralization of energy supply. Green spaces provide shading and cooling, reducing the need to air-condition buildings or to leave the city during heat waves. Green-roofing can save energy, attenuate storm water, and provide cooling. Synergies between

adaptation and mitigation are often related to building height, layout, spacing, materials, shading, ventilation, and air-conditioning.

Many climate-smart designs, combining ecological principles, social sensitivities, and energy efficiency, are planned for urban areas in China, such as Dongtan, close to Shanghai, but so far the plans have largely remained blueprints.

Sources: Girardet 2008; Laukkonen and others 2009; McEvoy, Lindley, and Handley 2006; Wang and Yaping 2004; World Bank 2008g; Yip 2008.

Map 2.3 Northern cities need to prepare for Mediterranean climate—now



Source: WDR team, reproduced from Kopf, Ha-Duong, and Hallegatte 2008.

Note: With increasing global temperatures, climate zones will shift north, and by the middle of the 21st century many central and northern European cities will “feel” Mediterranean. This is not good news and has major implications: water utilities will need to adjust management plans, and health services will need to be prepared for more extreme heat episodes (similar to the 2003 European heat wave). While a few degrees of warming may seem appealing on a cold winter day in Oslo (the scenario shown in the map corresponds approximately to a global temperature increase of 1.2°C relative to today), the necessary changes in planning, public health management, and urban infrastructure are substantial. Buildings that were designed and engineered for cold harsh winters will need to function in a drier and hotter climate, and heritage buildings may suffer irreparable damages. Even more challenging is the construction of new buildings today as their design needs to be highly flexible to gradually adjust to drastically different conditions over the coming decades.

BOX 2.5 Preparing for heat waves

After heat waves in 2003 the Spanish Ministry of Health and CatSalut (the regional Catalan health service) implemented a comprehensive interministerial and inter-agency action plan to blunt the effects of future heat waves on health.^a The plan incorporates health responses and communications (at all levels of health care) triggered by a heat-health warning system.

The plan has three levels of action during the summer season:

- Level 0 starts on June 1 and focuses on preparedness.
- Level 1 is triggered during July and August and focuses on meteorological assessments (including daily recordings of temperature and humidity), disease surveillance, assessment of preventive

actions, and protection of at-risk populations.

- Level 2 is activated only if the temperature rises above the warning threshold (35°C in coastal areas and 40°C in inland areas), at which point health and social care and emergency service responses are initiated.

The action plan and its health system response hinge on using primary health care centers (including social services) in the region. The centers identify and localize vulnerable populations to strengthen outreach to them and disseminate public health information during the summer. They also collect health data to monitor and evaluate the health impacts of heat waves and the effectiveness of interventions.

Similar actions are under way elsewhere. Wales has a framework for heat-wave preparedness and response. It establishes guidelines for preventing and treating heat-related illnesses, operates an early warning system during the summer months, and has communication mechanisms with the meteorological office.^b Metropolitan Shanghai has a heat-health warning system as part of its multi-hazard management plan.^c

Sources:

- a. CatSalut 2008.
- b. Welsh Assembly Government 2008.
- c. Shanghai Multi-Hazard Early Warning System Demonstration Project, <http://smb.gov.cn/SBQXWebInEnglish/TemplateA/Default/index.aspx> (accessed March 13, 2009).

in Eastern Europe and Central Asia.⁵⁷ Malaria already strains economies in tropical areas,⁵⁸ killing almost 1 million people a year (mostly children), and climate change is projected to expose 90 million more people (a 14 percent increase) to the disease by 2030 in Africa alone.⁵⁹ Dengue has been expanding its geographic range (map 2.4), and climate change is expected to double the rate of people at risk from 30 percent to up to 60 percent of the world population (or 5 billion to 6 billion people) by 2070.⁶⁰ To detect and monitor epidemic-prone diseases, national health systems need better surveillance and

early warning systems.⁶¹ Today, surveillance in many parts of the world fails to anticipate new disease pressure, for example, in Africa, where malaria is reaching urban dwellers with the expansion of urban settlements into areas of transmission.⁶² Satellite remote-sensing and biosensors can improve the accuracy and precision of surveillance systems and prevent disease outbreaks through early detection of changes in climate factors.⁶³ Advanced seasonal climate forecast models can now predict peak times for malaria transmission and give regional authorities in Africa information to operate

Map 2.4 Climate change accelerates the comeback of dengue in the Americas



Source: PAHO 2009.

Note: Infectious and vector-borne diseases have been expanding into new geographic areas all over the world. In the Americas the incidence of dengue fever has been rising because of increasing population density and widespread international travel and trade. Changes in humidity and temperature brought about by climate change amplify this threat and allows disease vectors (mosquitoes) to thrive in locations previously unsuitable for the disease; see Knowlton, Solomon, and Rotkin-Ellman 2009.

an early warning system and longer lead-times to respond more effectively.⁶⁴

Most measures to prevent these diseases are not new, but climate change makes the better implementation of well-established public health approaches even more urgent.⁶⁵ Breaking the transmission pathways requires better management of water (urban drainage), improved sanitation and hygiene (sewerage systems, sanitation facilities, hand-washing behaviors), and effective vector control to limit or eradicate insects that transmit disease pathogens.⁶⁶

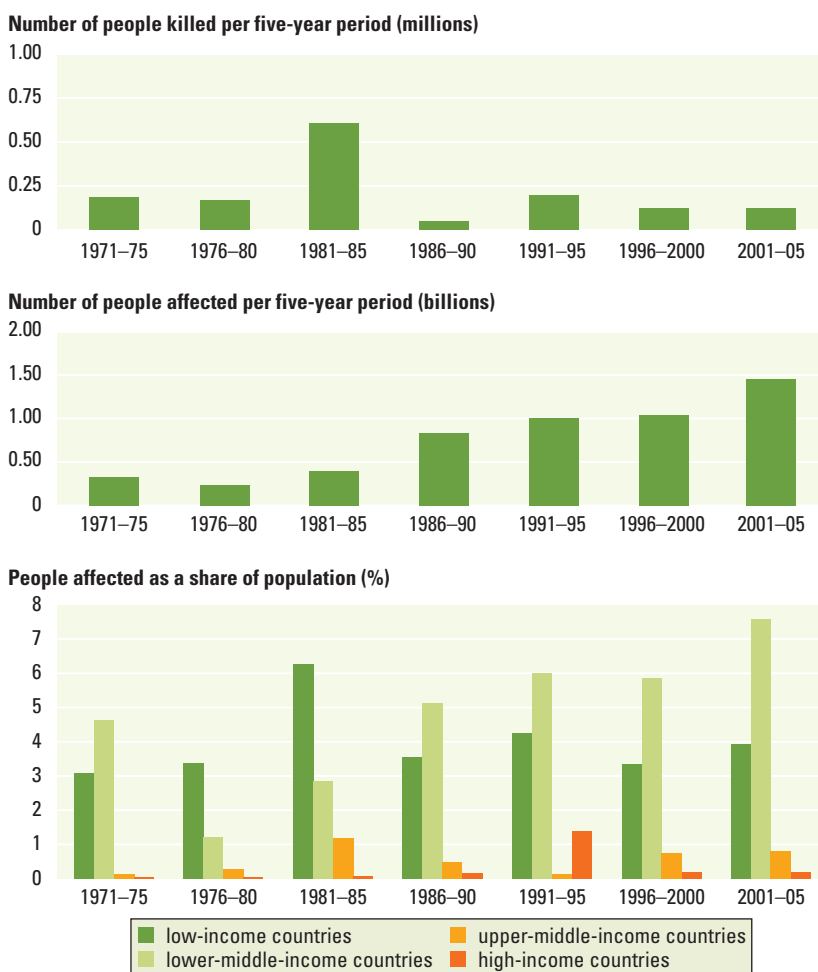
Such interventions require coordinated intersectoral action and public expenditures. For water-borne diseases, interventions should include the health agency, public works, and utilities.⁶⁷ Jointly managed water, sanitation, hygiene, and food security—combined with health and disaster management—can yield high returns. So can engaging the private sector, if it improves performance. Privatizing water services in Argentina in the 1990s dramatically reduced the child mortality linked to water-borne diseases.⁶⁸

Monitoring and managing the health impacts of climate change will require greater use of new diagnostic tools. Advances in genomics and information technology are accelerating the design of a wide range of diagnostic tools that can help in monitoring the spread of diseases and the emergence of new ones. New communications tools will make it easier to collect, analyze, and share health information in a timely manner.⁶⁹ But having such tools will not be sufficient without extensive programs to train health care workers. Similarly, major institutional reforms will need to be introduced to integrate health care into other activities. Schools, for example, can be major centers for the provision of basic health care as well as sources of medical information and education.

Prepare for extreme events

Natural disasters are taking an increasing economic toll, and managing them better is essential for adapting to climate change. While deaths from weather-related natural disasters are on the decline,⁷⁰ economic losses caused by storms, floods, and droughts are all rising (from about \$20 billion a year in the early 1980s to \$70 billion in the early 2000s for high-income countries and from \$10 billion a year to \$15 billion for low- and middle-income countries).⁷¹ But this increase is largely explained by higher exposure of economic value per area rather than changes in climate.⁷² The number of affected people (people requiring humanitarian assistance after disasters) continues to increase, with the largest share in lower-middle-income countries characterized by rapid urban growth (figure 2.1).⁷³ About 90 percent of the economic losses in developing

Figure 2.1 The number of people affected by climate-related disasters is increasing



Sources: WDR team; CRED 2009.

Note: Over the past 40 years the death toll has fallen but the number of people affected has doubled every decade. (People affected are those requiring immediate assistance during a period of emergency and can also include displaced or evacuated people.) In lower-middle-income countries almost 8 percent of the population is affected each year. The increase cannot be attributed only to climate change; much results from population increase, greater exposure of infrastructure and improved reporting of disasters. However, the impacts on people are just as real and show why it is so essential to begin focusing on the current adaptation deficit while looking ahead to a more climatically stressful future.

countries are borne by households, businesses, and governments with the rest covered by insurance or donor funds.

Unless disaster impacts are systematically reduced, past development gains will be at risk. So the focus is shifting from coping with disaster events to forward-looking disaster risk management and toward preventive rather than reactive measures. In line with the Hyogo Framework of Action for reducing disaster risks (the 2005 policy framework defined by the United Nations), recovery and reconstruction are being

designed to reduce risks of future disasters, bridging the humanitarian and development agendas.⁷⁴ The private sector is instrumental in this framework, providing financial (insurance, risk assessments) and technical (communication, construction, service provision) solutions.⁷⁵

Climate change greatly increases the need for effective management of extreme weather events and for disaster risk management that increases preparedness and prevents losses (box 2.6).⁷⁶ In many places previously uncommon risks are becoming more

BOX 2.6 *Beating the odds and getting ahead of impacts: Managing the risk of extreme events before they become disasters*

Recurrent extreme climate events—storms, floods, droughts, wildfires—characterize many parts of the world and are part of the climate system. Climate change is likely to change patterns of extreme events, but negative impacts can be reduced through systematic risk management. The basic steps are assessing risk, reducing risk, and mitigating risk.^a

Assessing risk, a prerequisite for risk management, is the basis for informed decision making. It focuses action and resources. Identifying pertinent risk is the first step and generally does not require sophisticated techniques. Rice farmers in Asia readily point out their most flood-prone fields. Water reservoir managers know the difficulties of managing the competing demands for electricity and water supply when water levels are low. And communities can identify social groups and individuals who tend to be affected first when adverse weather events occur.

Quantifying risk is the next step, and a variety of approaches exist depending on the scope of a risk assessment. Communities use simple participatory techniques based on readily observable indicators (such as the market price for staple crops during droughts) to trigger action at the household and community level, or they use community-based mapping to determine flood-prone areas. Risk assessments at the sector level (agriculture or hydro-power) or for a country generally require more systematic and quantitative data analysis (mapping agricultural extent or regional hydrology).

Understanding risk requires investment in scientific, technical, and institutional

capacity to observe, record, research, analyze, forecast, model, and map natural hazards and vulnerabilities. Geographic information systems can integrate these sources of information and give decision makers a powerful tool to understand risk—both at the national agencies and the local level. Many low- and middle-income countries are now performing risk assessments and are systematically strengthening their capacity to manage disasters better.^b

Reducing risk requires mainstreaming risk in the overall strategic framework of development, a task more important than ever as the density of people and infrastructure increases. Since the late 1990s there has been increasing recognition of the need to address risks emanating from natural hazards in medium-term strategic development frameworks, in legislation and institutional structures, in sectoral strategies and policies, in budgetary processes, in individual projects, and in monitoring and evaluation. Mainstreaming requires analysis of how potential hazard events could affect policies, programs, and projects and vice versa.

Development initiatives do not necessarily reduce vulnerability to natural hazards, and they can unwittingly create new vulnerabilities or heighten existing ones. Solutions for jointly sustaining development, reducing poverty, and strengthening resilience to hazards thus need to be explicitly sought. Disaster risk reduction should promote resilience and help communities adapt to new and increased risks. But even this cannot be guaranteed. For instance, investments in structural

flood control designed according to current probabilities could add to future losses by encouraging development in flood-prone areas today but leaving them more prone to future major damages. So climate-change predictions have to be taken into account in current decision making and longer-term planning.

Mitigating risk entails actions to minimize impacts during an event and its immediate aftermath. Early warning and surveillance systems harness information technology and communication systems to provide advance warnings of extreme events. For such information to save lives, disaster management agencies need mechanisms in place to receive and communicate information to communities well ahead of the event. This requires systematic preparedness training; capacity building and awareness raising; and coordination between national, regional, and local entities. Taking swift and targeted action after a disaster is equally important, including social protection for the most vulnerable and a strategy for recovery and reconstruction.

Sources: WDR team; Ranger, Muir-Wood, and Priya 2009; United Nations 2007; United Nations 2009; NRC 2006; Benson and Twigg 2007.

a. Here the term *mitigation* refers to avoidance of losses from extreme weather events, for example, by evacuating people from a flood plain, through short-term measures in anticipation of an immediate threat.

b. Global Facility for Disaster Reduction and Recovery, www.gfdrr.org (accessed May 15, 2009); Prevention, www.preventionconsortium.org (accessed May 15, 2009).

widespread, as in Africa, where the number of floods is increasing rapidly (figure 2.2), and in Brazil, which experienced the first South Atlantic hurricane ever in 2004.⁷⁷

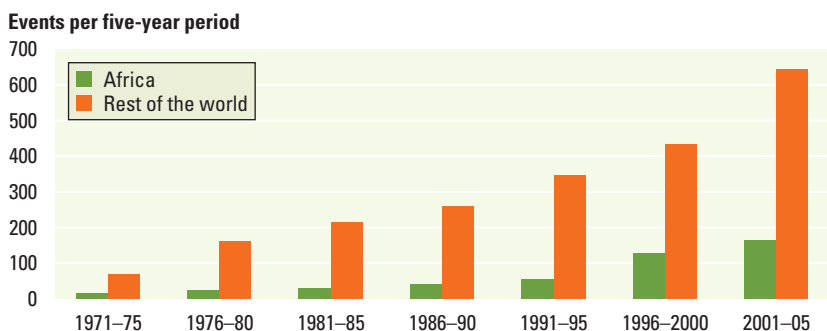
Generating information about where extreme weather impacts are likely and the consequences they may have requires socioeconomic data (maps showing population density or land values) as well as physical information (records of precipitation or extreme events).⁷⁸ But in a changing climate the past is no longer prologue (once-rare events may become more frequent), and uncertainty about the future climate is an important element in assessing risk and evaluating planning decisions. Equally important are monitoring and periodic updates in socioeconomic data to reflect

changes in land use and demographics. Satellite and geographic information technology provide powerful means to generate physical and socioeconomic information rapidly and cost-effectively (box 2.7; see also chapters 3 and 7).

Many developed countries provide detailed flood-risk maps as a public service to homeowners, businesses, and local authorities.⁷⁹ In China the government has drawn such maps since 1976 and publishes flood-risk maps that delineate high-risk zones for the most populated river basins. With such tools, residents can have information on when, how, and where to evacuate. The maps can also be used for land-use planning and building design.⁸⁰ Put in the hands of local communities, such services foster local action, as in Bogota, where similar risk-based information for earthquake-prone zones strengthens the resilience of communities.⁸¹

Risk can never be eliminated, and being prepared to cope with extreme events is vital for protecting people. Warning systems and response plans (say, for evacuation in an emergency) save lives and prevent avoidable losses. Engaging communities in preparedness and emergency communication protects their livelihoods. For example, in Mozambique communities along the Búzi River use radios to warn communities downstream of flooding.⁸² Even in remote, isolated communities local action can reduce risk, create jobs, and address poverty

Figure 2.2 Floods are increasing, even in drought-prone Africa



Source: WDR team analysis from CRED 2009.

Note: Flood events are increasing everywhere but particularly in Africa, with new regions being exposed to flooding and with less recovery time between events. Reporting of events may have improved since the 1970s, but this is not the main cause of rising numbers of reported floods, because the frequency of other disaster events in Africa, such as droughts and earthquakes, has not shown a similar increase.

BOX 2.7 Satellite data and geo-information are instrumental in managing risk—and inexpensive

Satellite data and geo-information technology are often available for free or at moderate cost, and the software and tools to use such technology operate on desktop computers.

Satellites monitor moisture and vegetation and provide invaluable information to agricultural extension services. They track tropical storms and provide early warning to coastal communities. By mapping flood impacts they support recovery and reconstruction operations. They map forests and biomass and

empower indigenous forest dwellers with information. High-resolution sensors identify urban encroachment into hazardous zones. Geographic positioning devices used in surveys can reveal new information about how households interact with the natural environment. Geo-information systems streamline data management, ensure information is available when it is needed, and provide a cost-effective and rapid tool to build the knowledge base for informed policy making and for understanding risk patterns in

places where such data and knowledge are currently limited.

The use of such services and technology broadly and effectively in developing countries does not require hard investments—investments in higher education, institutional capacity building, mission-focused regional research centers, and promoting private enterprise are the main elements.

Sources: ESA 2002; NRC 2007a, 2007b.

(box 2.8). At the national level, being financially prepared to provide immediate assistance after disasters is critical for avoiding long-term losses for communities.

Managing financial risks: Flexible instruments for contingencies

Public policy creates a framework that delineates clear roles and responsibilities for the public sector, private sector, households, and individuals. Core to such a framework is a spectrum of risk management practices with layered responsibilities. A minor drought that causes small losses in crop production can be managed by households through informal and community-based risk sharing unless several small droughts occur in short sequence (see chapter 1). A more severe drought, one that occurs, say, every 10 years, can be managed through risk transfer instruments in the private sector. But for the most severe and widespread events the government has to act as the insurer of last resort. It has to develop a framework that allows communities to help themselves and the private sector to play an active and commercially viable role, while making provisions to cover its liabilities arising from catastrophic events.

Provide layers of protection

The use and support of insurance mechanisms has gained much attention in the context of adaptation.⁸³ Insurance can protect against losses associated with extreme climate events and manage costs that cannot be covered by international aid, by governments, or by citizens.⁸⁴ Some novel approaches have been developed and tested, such as weather-based derivatives and microinsurance products on the private market. Consider the weather-index insurance for smallholder farmers in India that provides compensation to hundreds of thousands of farmers in case of severe precipitation shortfall—and the Caribbean common insurance pool that quickly provides governments with liquidity after disasters.⁸⁵

But insurance is not a silver bullet—it is only one element in a broader risk management framework that promotes risk reduction (avoiding avoidable losses) and rewards sound risk management practices (just as

BOX 2.8 *Creating jobs to reduce flood risk*

Heavy rains are common in Liberia, yet drainage systems have not been maintained for decades because of years of neglect and civil war. As a result, flooding has triggered recurrent disasters in both rural and urban settings. Cleaning the drains was not a priority for government officials or citizens, because nobody had the resources. But after Mercy Corps, an international nongovernmental organization, raised the possibility of cash-

for-work options, government officials embraced it. In September 2006 a one-year project to clear and rehabilitate drainage systems was launched in five counties. This significantly increased the flow of rainwater and reduced flooding and related health risks. The project also rehabilitated wells and improved market access by clearing roads and building small bridges.

Source: Mercy Corps 2008.

homeowners receive a premium reduction if they install fire alarms). If climate is trending in a predictable fashion (toward hotter or drier weather conditions, for instance), insurance is not viable. Insurance is appropriate when impacts are random and rare, helping households, businesses, and governments spread risk over time (by paying regular premiums rather than covering the full costs at once) and geographically (by sharing risk with others). So, it does not eliminate risk, but it does reduce the variance of losses borne by individuals in the insurance pool.

Insurance against storms, floods, and droughts, whether provided to governments or individuals, is difficult to manage. Climate risk tends to affect entire regions or large groups of people simultaneously; for example, thousands of breeders in Mongolia saw their livestock decimated in 2002, when a dry summer was followed by an extremely cold winter (box 2.9). Such covariant events characterize many climate risks and make insurance very difficult to provide because claims tend to cluster and require large backup capital and administrative efforts.⁸⁶ That is one reason major climate risks are not widely covered by insurance, particularly in the developing world. Indeed, microfinance institutions often limit the share of agricultural loans in their portfolio in case widespread weather impacts cause their clients to default.⁸⁷

The provision of financial services has been a long-standing challenge in development for reasons unrelated to climate change. Access to insurance products is generally much

BOX 2.9 *Public-private partnerships for sharing climate risks: Mongolia livestock insurance*

An important concept of climate-risk management is risk-sharing by communities, governments, and businesses. In Mongolia livestock herders, the national government, and insurance companies developed a scheme to manage the financial risks arising from severe winter-spring cold episodes (*dzuds*) that periodically result in widespread livestock mortality. Such episodes killed 17 percent of livestock in 2002 (in some areas up to 100 percent), amounting to losses of \$200 million (16 percent of GDP).

In this scheme herders retain the responsibility for smaller losses that do not affect the viability of their business or household, and they often use arrangements with community members to buffer against smaller losses. Larger losses (of 10–30 percent) are covered through

commercial livestock insurance provided by Mongolian insurers. A social insurance program through the government bears the losses associated with catastrophic livestock mortality that would overwhelm herders and insurers alike. This tiered approach defines a clear framework for self-insurance by herders, commercial insurance, and social insurance.

An important innovation is the use of index insurance rather than individual livestock insurance, which had been ineffective because the verification of individual losses tends to be fraught with moral hazard and often prohibitively high costs. With this new type of insurance, herders are compensated based on the average livestock mortality rate in their district, and an individual loss assessment is not required.

This gives Mongolian insurers incentives

to offer commercial insurance to herders, which they had been reluctant to do.

The scheme provides advantages for all. Herders can buy insurance against unavoidable losses. Insurers can expand their business in rural areas, strengthening the rural financial service infrastructure. The government, by providing a well-structured social insurance, can better manage its fiscal risk. Even though a catastrophic event exposes the government to significant potential risk, the government had been compelled politically to absorb even greater risk in the past. Because the government covers catastrophic outcomes, the commercial insurance, limited to moderate levels of mortality, can be offered at affordable rates.

Sources: Mahul and Skees 2007; Mearns 2004.

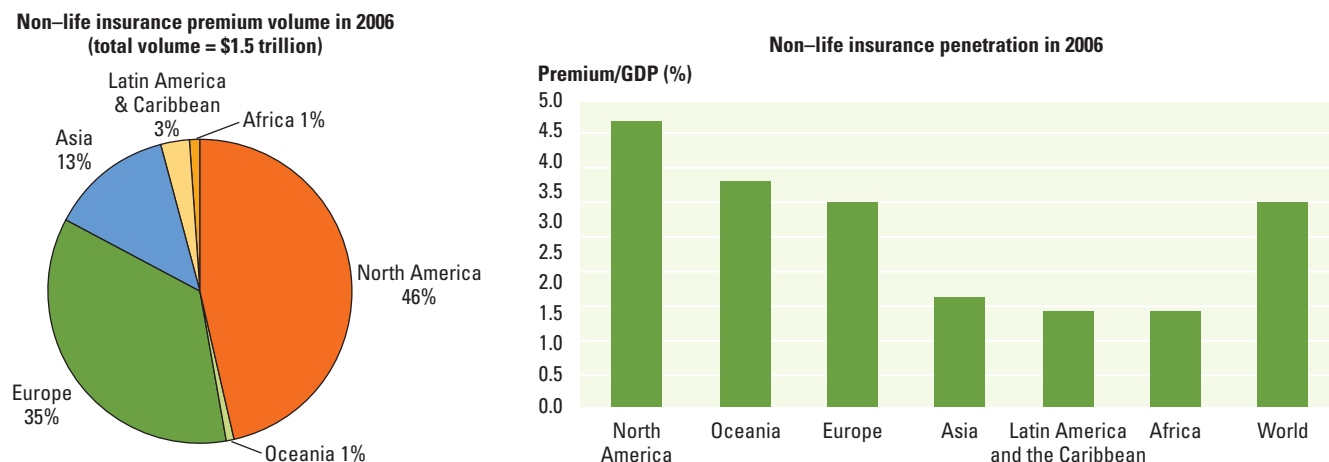
weaker in developing countries (figure 2.3), a fact reflected in the generally lower penetration of financial services in rural areas. The Philippines Crop Insurance Corporation, for example, reaches only about 2 percent of farmers, largely in the more productive and richer zones.⁸⁸ Providing financial services to rural populations is challenging and risky, because many rural households are not part of the monetized economy and have weather-sensitive livelihoods. In urban settings people are more concentrated, but it is still difficult to reach the poor in the informal economy.

Climate change could further erode the insurability of climate-related risk. Unchecked climate change could make many climate risks uninsurable or the premiums unaffordable. Insurability requires the ability to identify and quantify (or at least estimate partially) the likelihood of an event and the associated losses, to set premiums, and to diversify risk among individuals or collectives.⁸⁹ Meeting all three conditions makes a risk insurable but not necessarily profitable (as reflected in the low premium-to-claims ratio of many agricultural insurance programs) and the transaction costs of operating an insurance program can be considerable.⁹⁰ The uncertainties arising from climate change confound the actuarial processes that underlie

insurance markets.⁹¹ And diversifying risk will be more difficult as climate change leads to more synchronized, widespread, and systemic effects globally and regionally—effects that are difficult to offset in other regions or market segments.

The erosion of market-based insurability implies a strong reliance on governments as insurers of last resort, a role that many governments have implicitly taken. But the track record of governments has not been stellar, in either the developing world or the developed. For instance, Hurricane Katrina in 2005 bankrupted the U.S. flood insurance program 10 times over, with more claims in one year than in its 37-year history. And few government-sponsored crop insurance programs are financially sustainable without major subsidies.⁹² At the same time, if the magnitude of losses associated with recent catastrophic events is any indication of the insurability of future losses from climate change, it suggests a more explicit role of the public sector to absorb the damages that are beyond the private sector's capacity.⁹³

Insurance is no panacea for adapting to climate risks and is only *one* strategy to address *some* of the impacts of climate change. It generally is not appropriate for long-term and irreversible impacts, such as sea-level

Figure 2.3 Insurance is limited in the developing world

Source: Swiss Re 2007.

Note: Insurance is primarily a developed-country market as indicated by the regional share of premiums (left), and penetration (premium as percent of GDP) of non-life insurance (right). Non-life insurance includes property, casualty, and liability insurance (also referred to as general insurance), health insurance, and insurance products not defined as life insurance.

rise and desertification, trends that would lead to massive losses for insurers and thus be uninsurable. Insurance must also be considered within an overall risk-management and adaptation strategy, including sound regulation of land-use and building codes, to avoid counterproductive behavior—or maladaptation (such as continued settlement on a storm-prone coast)—because of the security in an insurance contract.⁹⁴

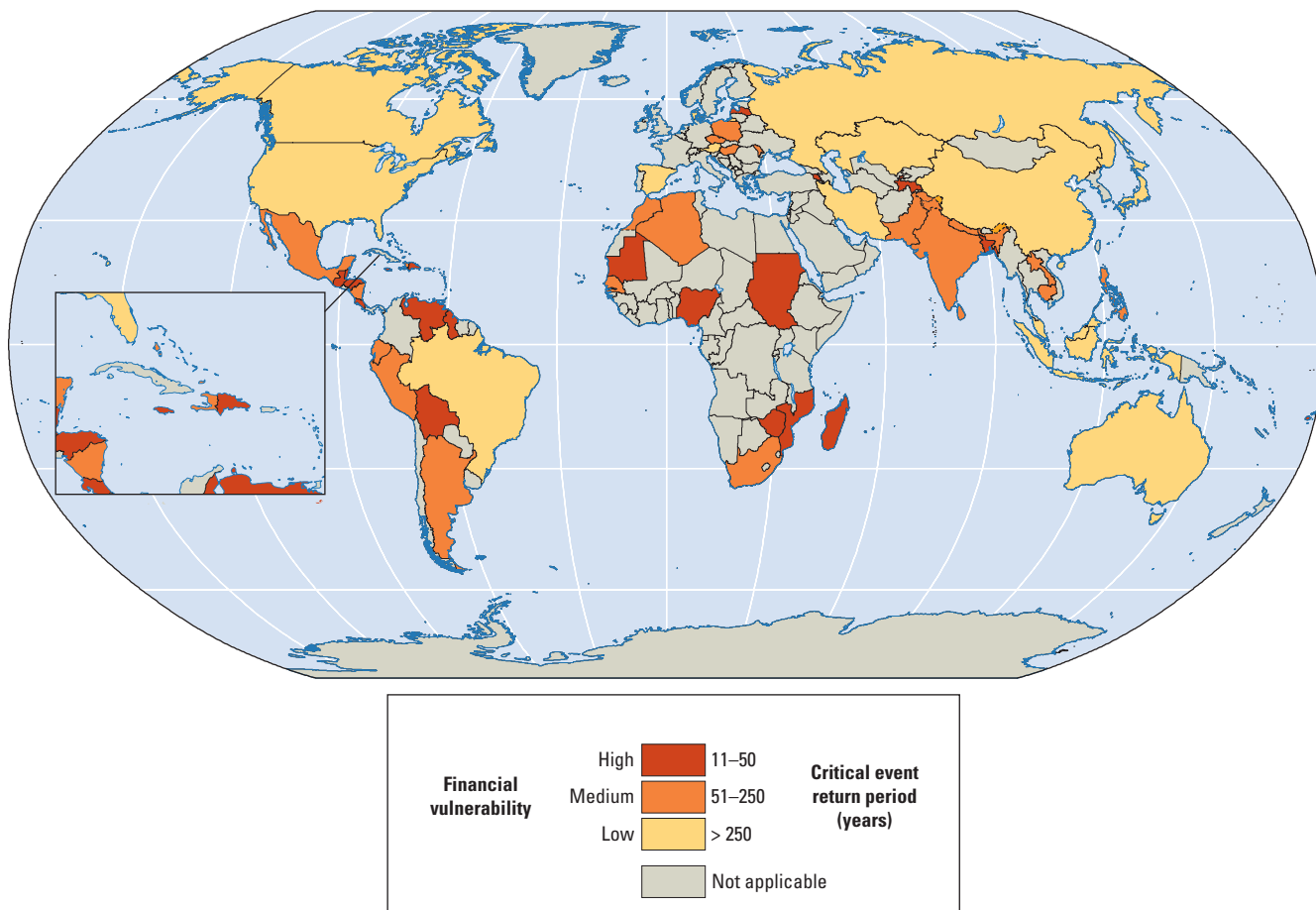
Keep governments liquid

Financial planning prepares governments for catastrophic climate impacts and maintains essential government services in the immediate aftermath of disasters.⁹⁵ Prearranged financing arrangements—such as catastrophe reserve funds, contingent lines of credit, and catastrophe bonds—allow governments to respond swiftly, scale up social protection programs, and avoid longer-term losses that accrue to households and communities while people are homeless, out of work, and experience basic deprivations.⁹⁶ Having immediate funds available to jumpstart the rehabilitation and recovery process reduces the derailing effect of disasters on development.

Many small countries are financially more vulnerable to catastrophic events because of the magnitude of disaster-related losses relative to the size of their economy (map 2.5); in Grenada in 2004,

for example, the winds of Hurricane Ivan caused losses equivalent to more than 200 percent of GDP.⁹⁷ Because outside aid is not always immediately available, 16 Caribbean countries have developed a well-structured financial risk-management scheme to streamline emergency funding and minimize service interruptions. Operating since 2007, it provides rapid liquidity to governments following destructive hurricanes and earthquakes, using innovative access to international reinsurance markets that can diversify and offset risk globally (box 2.10).

Even poor economies can manage climate risks more effectively by harnessing information, markets, good planning, and technical assistance. By forming partnerships with insurers and international financial institutions, governments can overcome the private sector's reluctance to commit capital and expertise to the low-income market. In 2008 Malawi pioneered a weather-based risk management contract to protect itself against droughts that would lead to national maize production shortfalls (often accompanied by high volatility in regional commodity prices and food insecurity). In exchange for a premium an international reinsurance company committed to pay an agreed amount to the government in case of predefined severe drought conditions, as measured and reported by

Map 2.5 Small and poor countries are financially vulnerable to extreme weather events

Source: Mechler and others 2009.

Note: The map shows degree to which countries are financially vulnerable to floods and storms. For example, in countries shaded dark red a severe weather event that would exceed the public sector's financial ability to restore damaged infrastructure and continue with development as planned is expected about once every 11 to 50 years (an annual probability of 2–10 percent). The high financial vulnerability of small economies underscores the need for financial contingency planning to increase governments' resilience against future disasters. Only the 74 most disaster-prone countries that experienced direct losses of at least 1 percent of GDP due to floods, storms, and droughts during the past 30 years were included in the analysis.

the Malawian weather service. The World Bank Treasury acted as a trusted intermediary to the market, increasing confidence in the transaction on both sides. Because payment and drought parameters were defined beforehand, disbursement from such a financial product could be rapid, and the government could forward-purchase maize on regional commodity markets to secure food as soon as possible before drought would affect the most vulnerable, which reduces response costs significantly, and decreases dependence on international appeals for assistance.⁹⁸

For these initiatives to be affordable and sustainable, disaster risk reduction needs

to be systematically promoted to minimize government reliance on such financial arrangements for more routine losses. Contingent financing has opportunity costs and should cover only the most urgent government financial needs and most extreme losses. Agricultural extension services, building code enforcement, and strategic urban planning are a few examples showing where government action can reduce avoidable consequences and the likelihood of the most extreme outcomes. Equally important are early warning systems that provide advance warning and prevent the loss of human life and economic damages. Such systems, supported by governments,

can have dramatic effects, as in Bangladesh, where they have reduced human deaths from floods and storms and therefore the need for the government to finance the losses.⁹⁹

Managing social risks: Empower communities to protect themselves

Climate change does not affect everyone equally.¹⁰⁰ For poor households even moderate climate stress can result in irreversible losses of human and physical capital.¹⁰¹ The impacts on children can be long term and affect lifetime earnings through education (withdrawal from school after a shock), health (compounding effect of poor sanitation and water- or vector-borne diseases), and stunting.¹⁰² Women in the developing world experience the effects of climate disproportionately because many of their household responsibilities (gathering and selling wild products) are affected by the vagaries of the weather.¹⁰³ Households and communities adapt through their livelihood choices, asset allocations, and locational preferences, often relying on traditional knowledge to inform these decisions.¹⁰⁴ People will be both more willing and more able to change if they have social support systems that combine community sharing, publicly provided social insurance (such as pensions), privately supplied finance and insurance, and publicly provided safety nets.

Build resilient communities

Building on local and traditional knowledge about managing climate risk is important for two reasons.¹⁰⁵ First, many communities, notably indigenous peoples, already have context-relevant knowledge and strategies for addressing climate risks. Efforts to marry development and climate adaptation for vulnerable communities will benefit from the ways people have always responded to environmental risks, as in Africa where communities have adapted to extended periods of drought.¹⁰⁶ But those traditional coping and adaptation strategies can prepare communities only for some perceived risks, not for the uncertain and possibly different risks brought by climate change.¹⁰⁷ In this way communities might be well adapted to their

BOX 2.10 *The Caribbean Catastrophe Risk Insurance Facility: Insurance against service interruption after disasters*

Among the many challenges facing the governments of small island states in the aftermath of natural disasters, the most urgent is obtaining access to cash to implement urgent recovery efforts and maintain essential government services. This challenge is particularly acute for Caribbean countries, whose economic resilience is limited by mounting vulnerability and high indebtedness.

The new Caribbean Catastrophe Risk Insurance Facility provides Caribbean Community governments with an insurance instrument akin to business interruption insurance. It furnishes short-term liquidity if they suffer catastrophic losses from a hurricane or earthquake.

A wide range of instruments exists to finance long-term recovery, but this facility fills a gap in financing short-term needs through parametric

insurance. It disburses funds based on the occurrence of a predefined event of a particular intensity, without having to wait for onsite loss assessments and formal confirmations. This type of insurance is generally less expensive and settles claims quickly, because measuring the strength of an event is almost instantaneous. The facility allows participating countries to pool their individual risks into one better-diversified portfolio and facilitates access to the reinsurance market, further spreading risks outside the region.

Such insurance mechanisms should be part of a comprehensive financial strategy using an array of instruments to cover different types of events and probabilities.

Sources: Ghesquiere, Jamin, and Mahul 2006; World Bank 2008e.

climates but less able to adapt to climate change.¹⁰⁸ Second, the local nature of adaptation means that sweeping policies with one-size-fits-all prescriptions are not suited to serving the needs of different urban and rural locations.¹⁰⁹

Building blocks of community resilience—the capacity to retain critical functions, self-organize, and learn when exposed to change—are evident throughout the world.¹¹⁰ In coastal Vietnam storm surges and rising sea levels are already putting stress on coping mechanisms. After cutbacks of many state services in the late 1990s, local collective decision making and credit and exchange networks substituted social capital and learning for government planning and infrastructure. (In recent years, however, the government has recognized its role to support community resilience and infrastructure development and now promotes a broad agenda of disaster risk management).¹¹¹

In the western Arctic the Inuit, experiencing diminished sea ice and shifting

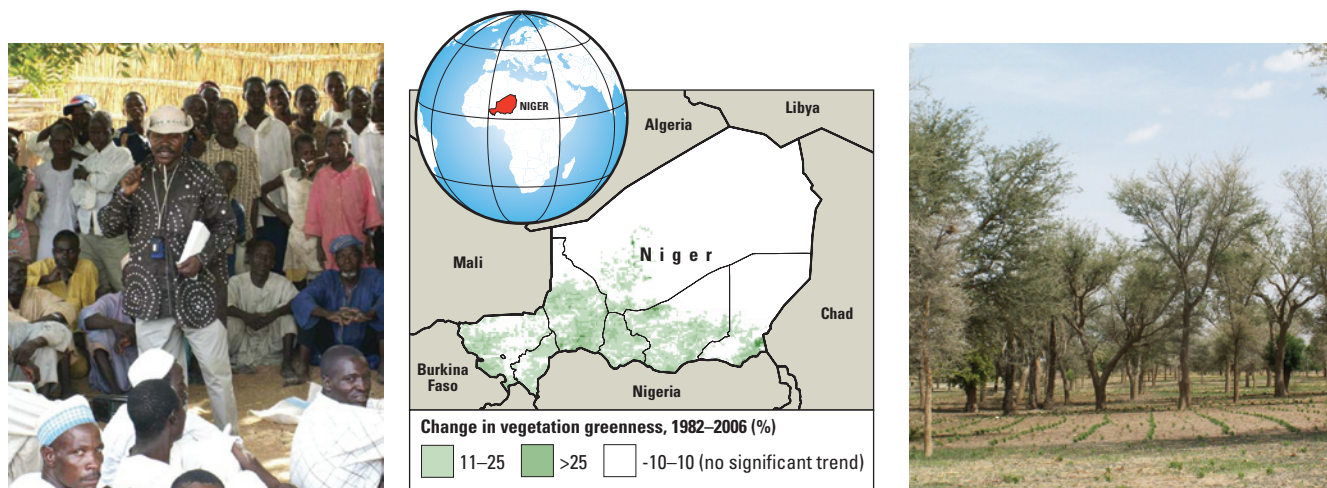
wildlife distributions, have adjusted the timing of subsistence activities and are hunting a greater variety of species. They are increasing the resilience of their communities by sharing food, trading more with one another, and by developing new local institutions.¹¹² Similarly, indigenous communities in developing countries are adapting to climate change—for instance, through rainwater harvesting, crop and livelihood diversification, and changes in seasonal migration—to alleviate adverse impacts and take advantage of new opportunities.¹¹³

In general, communities have better time-, place-, and event-specific knowledge of local climate hazards and of how such hazards affect their assets and productive activities. Communities also have greater capacity to manage local social and ecological relationships that will be affected by climate change. And they typically incur lower costs than external actors in implementing development and environmental projects (figure 2.4). A recent review of more than 11,000 fisheries found that the likelihood of stock collapse can be dramatically reduced by moving away from overall harvest limits

and introducing individual transferable catch quotas with local enforcement.¹¹⁴ Active participation of local communities and primary stakeholders in comanagement of fisheries is a key to success.¹¹⁵

Beyond resilience-enhancing benefits, decentralized resource management can have synergistic benefits for mitigation and adaptation. For example, forest commons management in tropical regions has produced simultaneous livelihood benefits (adaptation) and carbon storage gains (mitigation) when local communities own their forests, have greater decision-making autonomy, and ability to manage larger forest patches.¹¹⁶ In many developing countries decentralized governance of forests based on principles of common-pool resources has given local populations the authority to manage forests, use their time- and place-specific knowledge to create appropriate rules and institutions, and work with government agencies to implement the rules they have created.¹¹⁷ Enhancing indigenous peoples' land rights and ensuring their role in management has resulted in more sustained and cost-effective management

Figure 2.4 Turning back the desert with indigenous knowledge, farmer action, and social learning



Sources: WRI and others 2008; Botoni and Reij 2009; Herrmann, Anyamba, and Tucker 2005.

Note: In Niger farmers have turned back the encroaching desert; landscapes that were denuded in the 1980s are now densely studded with trees, shrubs, and crops. This transformation, so vast that its effects can be observed from satellites, has affected 5 million hectares of land (about the size of Costa Rica), which amounts to almost half of the cultivated land in Niger. The new economic opportunities created by the greening have benefited millions of people through increased food security and resilience to drought. Key to this success was a low-cost technique known as farmer-managed natural regeneration that adapts a centuries-old technique of woodland management. After some earlier success with the reintroduction of this indigenous technique in the 1980s, farmers saw the benefits and spread the word. The social learning effect was enhanced by donors supporting farmer study tours and farmer-to-farmer exchanges. The central government's role was pivotal in reforming land tenure and forest policies.

of forests and biodiversity resources, as in Mexico and Brazil.¹¹⁸

Effective community-based adaptation builds on social learning, the process of exchanging knowledge about existing experiences, and incorporating it with technical scientific information.¹¹⁹ When people migrate between urban and rural areas for seasonal employment or in the wake of natural disasters, their movements follow flows of earlier movements of relatives and friends.¹²⁰ When people adopt new technologies or change cropping patterns, their decisions depend on information flows in social networks.¹²¹ When people choose different areas to strengthen their skills and education, their decisions are tied to those of their peers.¹²²

Community and experience-based social learning has been a principal means to cope with climate risks in the past, but it may prove insufficient for climate change. Consequently, effective community-oriented climate adaptation strategies must balance the assets of communities (greater local capacity and knowledge, potential reserves of social capital, lower costs) against the deficits (limited scientific knowledge, narrow scope for action).

While numerous community-based adaptation activities are supported by a wide range of NGOs and other intermediaries, they reach only a minuscule fraction of those at risk. A pressing challenge is to replicate their successes far more widely. Scaling up has often been limited by poor links, and sometimes tensions, between local stakeholders and government institutions. Issues of authority, responsibility, and funding often impede cooperation. Successfully scaling up community-driven development will require that its supporters and governments think of the process beyond the project and of transformation or transition to avoid projects coming to a brutal end when funding stops. Capacity, pivotal to success, includes motivation and commitment, which in turn require appropriate incentives at all levels.¹²³ The new Adaptation Fund can greatly increase the support for scaling up because it is expected to manage resources on the order of \$0.5 billion to \$1.2 billion

by 2012 and to directly support governments at all levels, NGOs, and other intermediary agencies.¹²⁴

Provide safety nets for the most vulnerable

Climate change will amplify vulnerabilities and expose more people to climate threats more frequently and for longer periods. This requires social policies to assist groups whose livelihoods may gradually erode with climate change. Extreme events may also directly affect households and require safety nets (social assistance) to prevent the most vulnerable from falling economically. Protracted episodes of climate stress (as is common with drought) can contribute to commodity price increases and volatility, disproportionately affecting the poor and vulnerable, as was the case in the 2008 food crises.¹²⁵ High food prices increase poverty for those who need to purchase food to support their families, and worsen nutrition, reduce use of health and education services, and deplete the productive assets of the poor.¹²⁶ In parts of the developing world food insecurity and associated food price fluctuations already represent a systemic source of risk that is expected to increase with climate change.¹²⁷

Climate shocks have two important characteristics. First, there is uncertainty about who exactly will be affected and where. The affected population is often not identified until a crisis is well advanced, when it is difficult to respond swiftly and effectively. Second, the timing of possible shocks is not known ahead of time. Both aspects have implications for conceptualizing and designing social policies in response to future climate threats. Social protection should be thought of as a system, rather than isolated interventions, and should be put in place during good times. Safety nets need to have flexible financing and contingent targeting so they can be ramped up to provide effective responses for episodic shocks.¹²⁸

To address chronic vulnerabilities, a wide set of safety net instruments provides cash or in-kind transfers to poor households.¹²⁹ Used effectively, they have an

immediate impact on reducing inequality and are the first-best approach to addressing the poverty implications of commodity price increases; they allow households to invest in their future livelihoods and manage risk by reducing the incidence of negative coping strategies (such as selling of livestock during droughts). Safety nets can be designed to encourage households to invest in human capital (education, training, nutrition) that increases resilience in the long term.

In response to shocks, safety nets can have an insurance function if they are designed to be scalable and flexible. They are often phased, with the priorities shifting from immediate provision of food, sanitation, and cleanup to eventual recovery, rebuilding, and, possibly, disaster prevention and mitigation. To fulfill an insurance function, safety nets need countercyclical and scalable budgets, targeting rules to identify people with transitory needs, flexible implementation that allows rapid response following a shock, and basic organizational procedures and responsibilities agreed on well before a disaster.¹³⁰ Early warnings provided through seasonal forecasts and bulletins can mobilize safety nets ahead of time and prepare logistics and food deliveries.¹³¹

Safety nets will need to be strengthened substantially where they exist and developed where they are lacking. Many low-income countries cannot afford permanent transfers to their poor, but scalable safety nets that provide a basic form of noncontributory insurance can represent a core social protection that prevents mortality and excessive depletion of assets, even in poor countries where they have not commonly been used.¹³²

For instance, the Productive Safety Net in Ethiopia combines permanent social assistance (a longer-term workfare program targeted at 6 million food-insecure households) and scalable safety nets that can be rapidly expanded to serve millions of transitory poor households during a major drought. An important innovation is the use of indexes based on observed weather impacts to quickly provide more scalable and targeted assistance to food-insecure

areas and insurance-based mechanisms to access contingent financing.¹³³

Workfare programs can be part of a safety net's response.¹³⁴ They are labor-intensive public works programs that provide income to a target population while building or maintaining public infrastructure. These programs focus on assets and high-return activities that can increase the resilience of communities, such as water storage, irrigation systems, and embankments. To be fully effective, however, they need clear objectives, suitable and well-conceived projects, predictable funding, professional guidance in selection and implementation, and credible monitoring and evaluation (box 2.11).

Safety nets can also facilitate the reform of energy policy. Raising fuel prices brings energy efficiency, economic gains, and fiscal savings, but also brings significant political and social risks. Safety nets can protect the poor from high energy prices and help eliminate large, burdensome, regressive, and climate-damaging energy subsidies (see chapter 1).¹³⁵ Energy subsidies, a common response to high fuel prices, are often inefficient and not well targeted, but eliminating them is often problematic. Several middle-income countries (Brazil, China, Colombia, India, Indonesia, Malaysia, and Turkey) have recently used safety nets to facilitate the removal of fossil-fuel subsidies.¹³⁶ Cash transfer payments following the removal of subsidies must be carefully targeted to ensure that the poor are reasonably compensated—the reform in Indonesia showed that, even with substantial mistargeting, the bottom four deciles of the population still gained during the transfer period.¹³⁷

Facilitate migration in response to climate change

Migration will often be an effective response to climate change—and unfortunately the only response in some cases. Estimates of the number of people at risk of migration, displacement, and relocation by 2050 vary from 200 million to as high as 1 billion.¹³⁸ (But these estimates are based on broad assessments of people exposed to increasing risks rather than

BOX 2.11 *Workfare in India under the Indian National Rural Employment Guarantee Act*

India over time has developed an employment guarantee program built on an earlier successful scheme in the state of Maharashtra. The program establishes, through self-selection, the right of up to 100 days of employment at the statutory minimum wage for every household that volunteers. Households do not have to demonstrate need, and some wages are paid even if work cannot be provided.

The program makes provision for at least a third of the work to be available to women, on-site child care, and medical insurance for work injuries; work must be provided promptly and within five

kilometers of the household where possible. The operation is transparent with lists of works and contractors publicly available and on the program's Web site, allowing public oversight against corruption and inefficiency. Since the program's inception in 2005, 45 million households have contributed 2 billion days of labor and undertaken 3 million tasks.^a

With appropriate guidance, the program can support climate-smart development. It operates at scale and can direct significant labor toward appropriate adaptive works, including water conservation, catchment protection, and

plantations. It provides funds for tools and other items necessary to complete activities and technical support for designing and implementing the projects. It can thus become a core part of village development through productive, climate-resilient asset creation and maintenance.^b

Sources:

a. National Rural Employment Guarantee Act—2005, <http://nrega.nic.in/> (accessed May 2009).

b. CSE India, http://www.cseindia.org/programme/nrml/update_january08.htm (accessed May 15, 2009); CSE 2007.

analyses of whether exposure will lead them to migrate.¹³⁹) Adaptation, such as coastal protection, will offset climate impacts and reduce migration.¹⁴⁰

Today's movements are a crude guide to the geography of movements in the near future (box 2.12). Migration related to climate change is likely to be predominantly from rural areas in developing countries to towns and cities. Policies to facilitate migration should consider that most of the world's migrants move within their own countries and that the migration routes used by economic and involuntary migrants overlap significantly.

Little evidence suggests that migration caused by climate change provokes or exaggerates conflict, but that could change. People migrating because of environmental changes are likely disempowered, with little capacity to wage conflict.¹⁴¹ Where migration coincides with conflict, the relationship may not be causal.¹⁴² Similarly, the link between violent conflict and resource scarcity (water wars)¹⁴³ or degradation has rarely been substantiated (poverty and dysfunctional institutions have more explanatory power).¹⁴⁴ But uncertainty about the causal chains does not imply that future climate-induced migration would not increase the potential for conflict when coinciding with pressure on resources, food insecurity, catastrophic events, and lack of governance in the receiving region.¹⁴⁵

The negative portrayal of migration can foster policies that seek to reduce and control its incidence and do little to address the needs of those who migrate, when migration may be the only option for those affected by climate hazards. Indeed, policies designed to restrict migration rarely succeed, are often self-defeating, and increase the costs to migrants and to communities of origin and destination.¹⁴⁶ In facilitating migration as a response to climate impacts, it is better to formulate integrated migration and development policies that address the needs of voluntary migrants and support their entrepreneurial abilities and technical skills.

To the extent possible, policies should discourage settlement of migrants in areas with high exposure to persistent climate hazards (map 2.6). Between 1995 and 2005, 3 million people were displaced by civil unrest in Colombia, mostly to small or mid-sized cities. Many have moved to marginal city areas prone to flooding or landslides or near waste dumps, while their lack of education and job skills leaves them earning only 40 percent of the minimum salary.¹⁴⁷ Anticipating involuntary migration and resettlement, forward-looking plans should identify alternative sites, apply compensation formulas that allow migrants to relocate and develop new sources of livelihoods, and build public and social infrastructure for community life. Again, such policies

BOX 2.12 *Migration today*

The estimates of climate-change-induced migration are highly uncertain and ambiguous. In the short term climate stress is likely to add incrementally to existing migration patterns (map at left) rather than generating entirely new flows of people. The majority of the world's migrants move within their own countries. For example, there are nearly as many internal migrants in China alone (about 130 million) as there are international migrants in all countries (estimated to be 175 million in 2000). Most internal migrants are economic migrants, moving from rural to urban areas. There is also significant, if poorly estimated, rural-rural migration, which tends to smooth demand and supply in rural labor markets, and which serves as a step in the migration path of rural migrants.

International migration is largely a phenomenon in the developed world. Of international migrants, about two-thirds move between developed countries. The growth in new arrivals is higher in the developed than the developing countries,

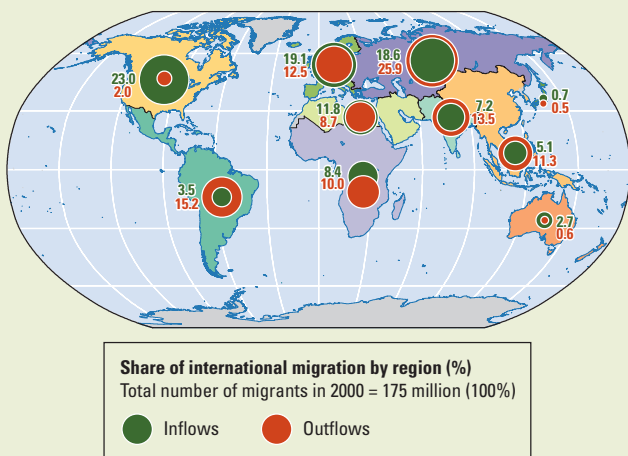
and about half of all international migrants are women. Half of the world's international migrants originate from 20 countries. Less than 10 percent of the world's international migrants are people forced to cross an international border for fear of persecution (the definition of refugees). Many forced migrants, however, fall under the definition of internally displaced persons (map at right), estimated to number 26 million people globally. The routes and intermediaries used by migrants fleeing conflicts, ethnic strife, and human rights violations are increasingly the same as those used by economic migrants. The available international statistics do not allow a specific attribution of internal displacement due to environmental degradation or natural disasters, but most of the forced migration linked to climate change is likely to remain internal and regional.

Migration flows are not random, but patterned, with flows of migrants concentrating around places where existing migrants have demonstrated that a life can be established and can help future

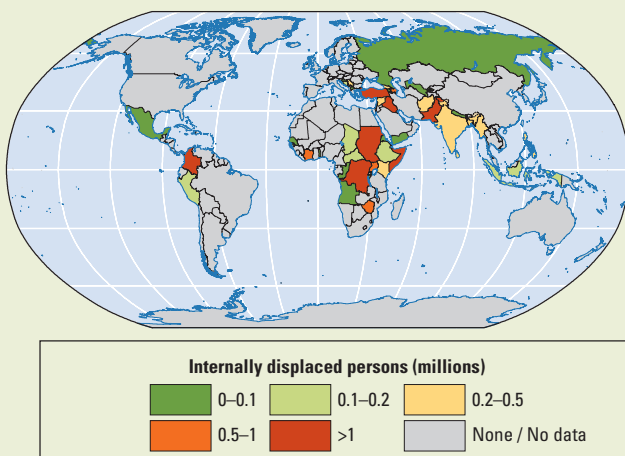
migrants to overcome the barriers to movement. These patterns are largely explained by barriers to movement and the requirements to overcome them. Barriers include financial ones as the costs of transport, housing on arrival, and living expenses while developing new income streams. Observations suggest that there is a "migration hump," where the rate of migration from a community increases as incomes rise beyond a level necessary to meet subsistence needs, and then decreases again as the gap between incomes at the place of origin and the main destination closes. The migration hump explains why the poorest of the poor do not migrate or migrate only very short distances.

Sources: Tuñón 2006; World Bank 2008f; United Nations 2005; United Nations 2006; Migration DRC 2007; de Haas 2008; Lucas 2006; Sorensen, van Hear, and Engberg-Pedersen 2003; Amin 1995; Lucas 2006; Lucas 2005; Massey and Espana 1987; de Haan 2002; Kolmannskog 2008.

International labor migration



Internal displacement



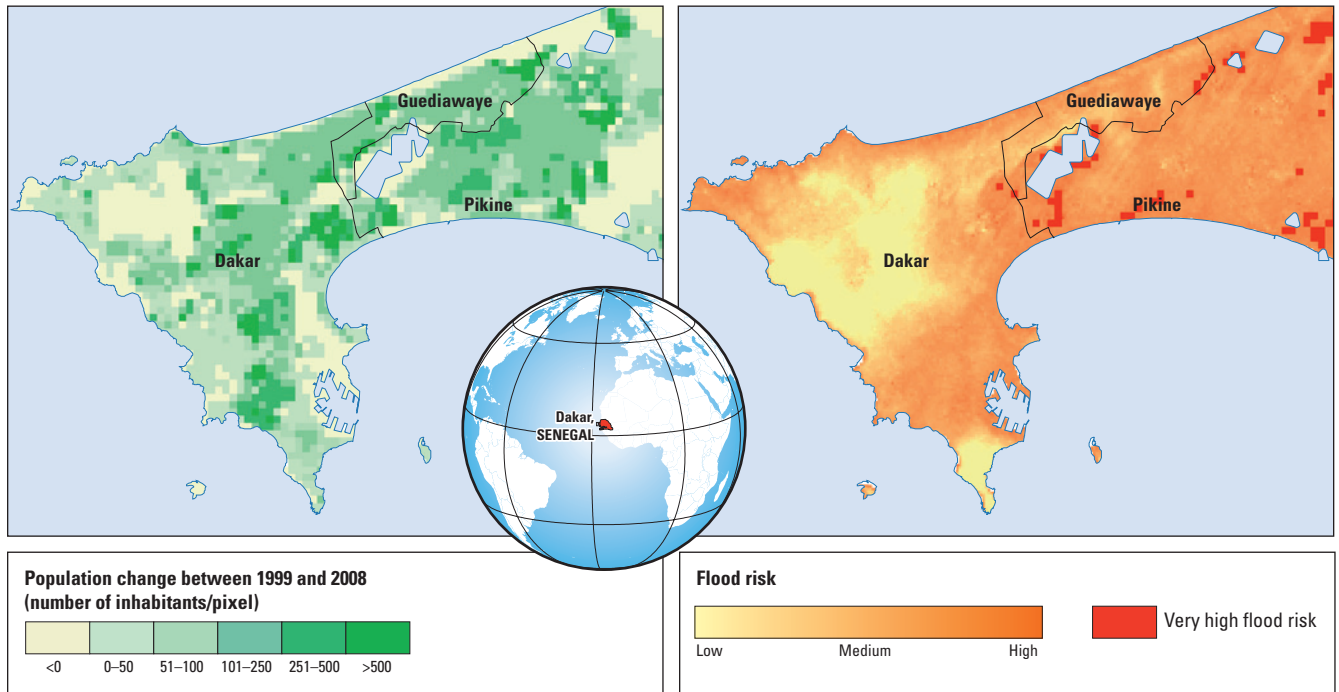
Sources: Parsons and others 2007; IDMC 2008

stand in sharp contrast to many ongoing efforts to address the needs of involuntary migrants and refugees—whether they are internally displaced or cross international borders.

Recent experience has suggested some lessons for resettling migrants. The first is to involve the communities to be resettled

in planning the move and in reconstruction—and to rely as little as possible on outside contractors and agencies. Those being resettled must receive compensation at the standards and prices in the receiving region, and they should be involved in the design and construction of infrastructure in the new location. Where possible, the

Map 2.6 Senegalese migrants settle in flood-prone areas around urban Dakar



Source: Geoville Group 2009.

Note: Slow economic growth in the agricultural sector has made Dakar the destination of an exodus from the rest of the country. Forty percent of Dakar's new inhabitants between 1988 and 2008 have moved into zones of high flood potential, twice as high as that of Dakar's urban (19 percent) and rural communes (23 percent). Because urban expansion is geographically limited, the influx of migrants has resulted in a very high concentration of people in urban and peri-urban zones (in the map, 16 pixels constitute one square kilometer).

decision-making structures in the community being resettled should be respected to the fullest extent.

Looking ahead to 2050: Which world?

A recurring theme of this Report is that the inertia in social, climate, and biological systems supports the case for action now. Some children alive today will be in

leadership positions in 2050. On a path to a 2°C warmer world, they will face dramatic changes. However, managing these changes will be but one of their many challenges. Heading toward a 5°C warmer world, the outlook will be far more dismal. It will be clear that mitigation efforts over more than half a century have been inadequate. Climate change will not be simply one of many challenges—it will be the dominant challenge.

“I would like to reach out to our world leaders to help initiate educational awareness and local government efforts to empower children to protect and restore the environment. Social and Political Institutions must respond and adapt strategies to protect public health, particularly for children. As a fifth grader, I think these are possible ways in order to ensure the survival of our Mother Earth.”

—Dave Laurence A. Juntilla, Philippines, age 11

Raisa Kabir, Bangladesh, age 10

Notes

1. WRI and others 2008; Heltberg, Siegel, and Jorgensen 2009.
2. Tompkins and Adger 2004.
3. Enfors and Gordon 2008.
4. The first is approximately the B1 SRES scenario where the world is on track to stabilization of greenhouse gases at 450–550 ppm CO₂e and eventually a temperature of about 2.5°C above preindustrial levels, and the second where emissions are significantly higher is approximately the A1B SRES scenario, which would lead to stabilization at about 1,000 ppm and eventually temperatures about 5°C above preindustrial levels; see Solomon and others 2007.
5. Horton and others 2008; Parry and others 2007; Rahmstorf and others 2007.
6. Allan and Soden 2008.
7. WBGU 2008.
8. Adger and others 2008.
9. Repetto 2008.
10. Lempert and Schlesinger 2000.
11. Keim 2008.
12. Millennium Ecosystem Assessment 2005.
13. Ribot, forthcoming.
14. Lempert and Schlesinger 2000; Lempert 2007.
15. Lewis 2007.
16. Lempert and Schlesinger 2000; Lempert and Collins 2007.
17. Bazerman 2006.
18. Groves and Lempert 2007.
19. Ward and others 2008.
20. Hallegatte 2009.
21. Pahl-Wostl 2007; Brunner and others 2005; Tompkins and Adger 2004; Folke and others 2002.
22. Cumming, Cumming, and Redman 2006.
23. Olsson, Folke, and Berkes 2004; Folke and others 2005; Dietz, Ostrom, and Stern 2003.
24. Dietz and Stern 2008.
25. Ligeti, Penney, and Wieditz 2007.
26. Pahl-Wostl 2007.
27. FAO and CIFOR 2005.
28. United Nations 2008b.
29. United Nations 2008a.
30. Balk, McGranahan, and Anderson 2008. Low-elevation coastal zones are defined as coastal land below 10 meters elevation; see Socioeconomic Data and Application Center, <http://sedac.ciesin.columbia.edu/gpw/lecz.jsp> (accessed January 8, 2009).
31. McGranahan, Balk, and Anderson 2007.
32. The net migration rate in Shanghai has been 4–8 percent, compared with approximately minus 2 percent attributable to natural growth between 1995 and 2006; see United Nations 2008a.
33. Nicholls and others 2008.
34. Simms and Reid 2006.
35. World Bank 2008a.
36. Seo 2009.
37. World Bank 2008g.
38. World Bank 2008g.
39. Using a \$2.15 a day poverty line; see Ravalion, Chen, and Sangraula 2007.
40. United Nations 2008a.
41. Satterthwaite 2008.
42. Díaz Palacios and Miranda 2005.
43. Pelling 1997.
44. World Bank 2008c.
45. Hara, Takeuchi, and Okubo 2005.
46. Bates and others 2008.
47. World Bank 2008a.
48. Satterthwaite and others 2007.
49. McEvoy, Lindley, and Handley 2006.
50. Laryea-Adjei 2000.
51. Confalonieri and others 2007.
52. Only includes major cause-specific mortality and excludes indirect effects and morbidity; see McMichael and others 2004; Global Humanitarian Forum 2009.
53. World Bank 2008b.
54. Robine and others 2008.
55. Solomon and others 2007; Luber and McGeehin 2008.
56. Corburn 2009.
57. Fay, Block, and Ebinger 2010.
58. Gallup and Sachs 2001.
59. Hay and others 2006; this estimation only accounts for the expansion of the disease vector; population growth will compound this effect and increase the population at risk by 390 million people (or 60 percent) relative to the 2005 population baseline.
60. Hales and others 2002; without climate change only 35 percent of the projected global population in 2085 would be at risk.
61. WHO 2008; de la Torre, Fajnzylber, and Nash 2008.
62. Keiser and others 2004.
63. Rogers and others 2002.
64. World Climate Programme 2007.
65. WHO 2005; Frumkin and McMichael 2008.
66. Better sanitation and hygiene are good for health, as evidenced by the impact of sanitation improvements on urban child health in Salvador, Brazil, a city with 2.4 million people. The program reduced the prevalence of diarrheal diseases by 22 percent across the city in 2003–04 and by 43 percent in high-risk communities. The improvements were mostly attributable to new infrastructure (Barreto and others 2007).
67. AMWA 2007.

68. Galiani, Gertler, and Schargrotsky 2005.
69. Richmond 2008.
70. A growing body of evidence suggests that existing disaster loss data miss most of the small events that may account for as much as a quarter of deaths attributed to natural hazards, and that decision makers in many municipalities have relatively low awareness of the risks climate change poses for their cities' populations and infrastructure; see Awuor, Orindi, and Adwera 2008; Bull-Kamanga and others 2003; Roberts 2008.
71. Hoeppe and Gurenko 2006.
72. United Nations 2009.
73. United Nations 2008a.
74. International Strategy for Disaster Reduction, <http://www.unisdr.org/eng/hfa/hfa.htm> (accessed March 12, 2009).
75. World Economic Forum 2008.
76. Milly and others 2002.
77. The Nameless Hurricane, http://science.nasa.gov/headlines/y2004/02apr_hurricane.htm (accessed March 12, 2009).
78. Ranger, Muir-Wood, and Priya 2009.
79. An example is the information services provided by the Scottish Environment Protection Agency, www.sepa.org.uk/flooding (accessed March 12, 2009).
80. Lin 2008.
81. Ghesquiere, Jamin, and Mahul 2006.
82. Ferguson 2005.
83. Linnerooth-Bayer and Mechler 2006.
84. Mills 2007.
85. Manuamorn 2007; Giné, Townsend, and Vickery 2008; World Bank 2008e.
86. Hochrainer and others 2008.
87. Christen and Pearce 2005.
88. Llanto, Geron, and Almario 2007.
89. Kunreuther and Michel-Kerjan 2007; Tol 1998.
90. World Bank 2005.
91. Mills 2005; Dlugolecki 2008; ABI 2004.
92. Skees 2001.
93. This raises important issues: land-use regulation and codes are required and need to be enforced. Mandatory insurance may be required by law in high-risk areas. There are also equity concerns: what to do with people who have lived in high-risk areas all along but cannot afford true risk-based premiums?
94. Kunreuther and Michel-Kerjan 2007.
95. Cummins and Mahul 2009.
96. See Cardenas and others 2007 for an example of the use of market instruments for sovereign financial risk management for natural disasters in Mexico.
97. Mechler and others 2009.
98. World Bank to Offer Index-based Weather Derivative Contracts, <http://go.worldbank.org/9GXG8E4GP1> (accessed May 15, 2009).
99. Government of Bangladesh 2008.
100. Bankoff, Frerks, and Hilhorst 2004.
101. Dercon 2004.
102. Alderman, Hoddinott, and Kinsey 2006; Bartlett 2008; UNICEF 2008; del Ninno and Lundberg 2005.
103. Francis and Amuyunzu-Nyamongo 2008; Nelson and others 2002.
104. Ensor and Berger 2009; Goulden and others 2009; Gaillard 2007.
105. Adger and others 2005; Orlove, Chiang, and Cane 2000; Srinivasan 2004; Wilbanks and Kates 1999.
106. Stringer and others, forthcoming; Twomlow and others 2008.
107. Nelson, Adger, and Brown 2007.
108. Walker and others 2006.
109. Gaiha, Imai, and Kaushik 2001; Martin and Prichard 2009.
110. Gibbs 2009.
111. Adger 2003.
112. Berkes and Jolly 2002.
113. Macchi 2008; Tebtebba Foundation 2008.
114. Costello, Gaines, and Lynham 2008.
115. Pomeroy and Pido 1995.
116. Chhatre and Agrawal, forthcoming.
117. Ostrom 1990; Berkes 2007; Agrawal and Ostrom 2001; Larson and Soto 2008.
118. Sobrevila 2008; White and Martin 2002.
119. Bandura 1977; Levitt and March 1988; Ellison and Fudenberg 1993; Ellison and Fudenberg 1995.
120. Granovetter 1978; Kanaiaupuni 2000; Portes and Sensenbrenner 1993.
121. Buskens and Yamaguchi 1999; Rogers 1995.
122. Foskett and Helmsley-Brown 2001.
123. Gillespie 2004.
124. World Bank 2009.
125. Ivanic and Martin 2008.
126. Grosh and others 2008.
127. Lobell and others 2008.
128. Kanbur 2009; Ravallion 2008.
129. Grosh and others 2008.
130. Grosh and others 2008; Alderman and Haque 2006.
131. Famine Early Warning Systems Network, www.fews.net (accessed May 15, 2009).
132. Alderman and Haque 2006; Vakis 2006.
133. Hess, Wiseman, and Robertson 2006.
134. del Ninno, Subbarao, and Milazzo 2009.
135. IEG 2008; Komives and others 2005.
136. World Bank 2008d.
137. World Bank 2006.

138. Myers 2002; Christian Aid 2007.
 139. Barnett and Webber 2009.
 140. Black 2001; Anthoff and others 2006.
 141. Gleditsch, Nordås, and Salehyan 2007.
 142. Reuveny 2007.
 143. Barnaby 2009.
 144. Theisen 2008; Nordås and Gleditsch 2007.
 145. WBGU 2008; Campbell and others 2007.
 146. de Haas 2008.
 147. Bartlett and others 2009.

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