SUSTAINABLE DEVELOPMENT IN AFRICA

edited by

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CONCEPTS AND METHODOLOGICAL APPROACHES

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Chapter 5

Concepts, Frameworks, and Policy Tools for Disaster Risk Management: Linking with Climate Change and Sustainable Development

Masahiko Haraguchi and Upmanu Lall

Introduction

Extreme weather and climate events challenge sustainable development. Due to changes in climate, land use, human settlement, and socioeconomic systems, the impacts of disasters is changing. In West Africa, more than 3.2 million people have been affected by floods since 2000 (UNOCHA, 2009), a far greater number than in the past. Both fatalities and economic effects are of interest. Historical trends show that the number of fatalities due to disasters is decreasing drastically, while the numbers of disasters, affected people and economic losses are increasing. An example of why this might be so comes from Thailand, where GDP growth declined by 75% due to floods in 2011 (Haraguchi and Lall, 2015). The economic losses increased because industrial parks, which were built over paddy fields, were inundated (Haraguchi and Lall, 2015). Similarly, since 1870 in Europe, flood fatalities have decreased drastically, while the number of people affected by flooding has increased (Paprotny et al., 2018).

Climate change policy and disaster risk management (DRM) have common elements. However, there are differences between these two agendas (Schipper and Pelling, 2006). First, climate change policy deals exclusively with climate or weather-related hazards and impacts, excluding geophysical disasters that DRM needs to address, such as earthquakes, tsunamis, and volcanic activity. Second, the time scales of climate change adaptation and disaster risk management are dissimilar. Disaster impacts are immediate (e.g., earthquakes, flash floods) or relatively short-term (e.g., fluvial floods, cyclones), although some climatological disasters, such as droughts and wildfires, could last longer—sometimes decades or even centuries. In contrast, climate change adaptation requires longer time frames.

Examples include adaptation to gradual changes in rainfall patterns affecting agriculture and water supplies, sea level rises and salt-water intrusion in coastal areas, glacial melting, and changes in temperature affecting land cover and ecosystems (World Bank, 2013). The purpose of this chapter is to provide the foundation for understanding the current status of disaster risk management in relation to climate change and sustainable development, and to introduce concepts and frameworks to effectively analyse the relevant issues.

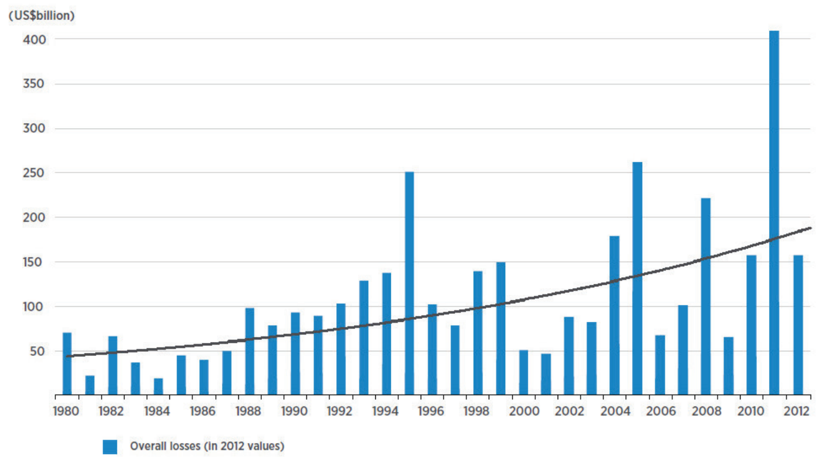

FIGURE 5.1. Global disaster losses from 1980 to 2012. The bars indicate annual disaster losses. The line indicates the trend. Source: Adapted from World Bank (2013)

An emerging issue in disaster risk management is economic vulnerability. Economic losses due to disasters at the global scale are increasing, with large spatial and interannual variability. Economic losses associated with disasters amounted to US$3,800 billion worldwide, as shown in Figure 5.1, which indicates the increasing trend worldwide. Furthermore, some 87% of 18,200 reported disasters, 74% of US$ 2,800 billion of losses, and 61% of the 1.4 million lost lives were attributed to weather and climate-related extremes (World Bank, 2013). Due to the changes in vulnerability and exposure, such as increases in the concentration of population and assets as well as in property values, increases in economic damages and losses are particularly significant in developed and emerging countries (Kunreuther and Michel-Kerjan, 2011; Michel-Kerjan and Kunreuther, 2011). Climate impacts can be spatially correlated and temporally clustered, as illustrated in Bonnafous et al. (2017a) and Bonnafous et al. (2017b). Thus, supply chains associated with metals, agricultural products and manufacturing in general could be exposed to significant losses that would manifest as indirect damages from climate hazards (Haraguchi and Lall, 2015).

The Intergovernmental Panel on Climate Change (IPCC, 2012) has reported that it is highly confident that economic losses caused by weather and climate-related disasters have increased, although large spatial and interannual variability exists (Tanoue et al., 2016; Paprotny et al., 2018). Furthermore, IPCC (2012) is highly confident that the severity of the impacts of weather and climate extremes is strongly associated with the degree of society's exposure and vulnerability to these extremes. After adjusting long-term trends of economic losses for economic assets and population, IPCC (2012) estimated that the primary cause of long-term increases in economic losses from weather and climate-related disasters has been people's increased exposure and economic assets, which are closely connected with development process, rather than climate change. Thus, disaster risk and its components—hazards, exposure, and vulnerability—will be reviewed in the next section.

Concepts of Disaster Risk Management in a Development Context

Definition and Characteristics of Disaster Risk

Here, disasters are defined as adverse impacts that "produce widespread damage and cause severe alteration in the normal functioning of communities or societies" (IPCC, 2012). Disaster risk can be defined as a function of type, magnitude, and duration of the hazard, exposure, and vulnerability (World Bank, 2013).

- A hazard is "the potential occurrence of a natural or human-induced physical event that may cause loss of life, injury or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision and environmental resources" (IPCC, 2007; IPCC, 2012; World Bank, 2013).
- Exposure is defined as "the presence of people; livelihoods; environmental services and resources; infrastructure; or economic, social, or cultural assets in places that could be adversely affected (e.g., transmitting facility in a coastal area)" (IPCC, 2012; World Bank, 2013).
- Vulnerability is defined as "the propensity or predisposition to be adversely affected" (IPCC, 2012).

As Figure 5.2 shows, natural hazards, exposure, and vulnerability jointly define disaster risk. Therefore, changes in any of these three components would lead to changes in disaster risks. This means disaster risk management involves addressing a combination of natural and socioeconomic drivers.

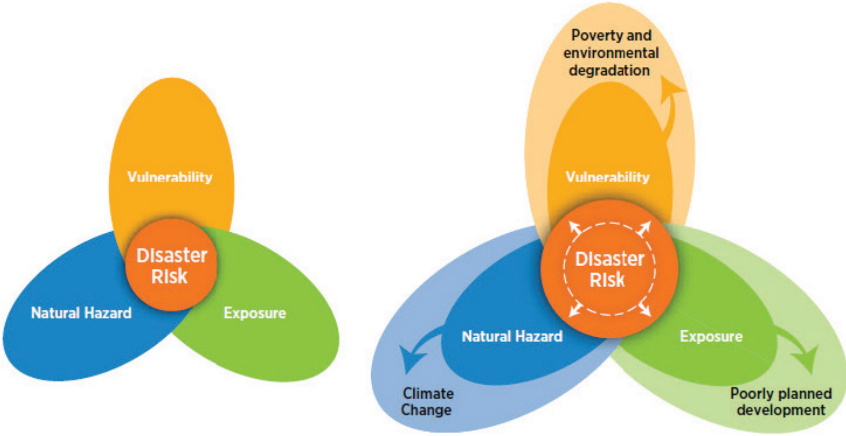

FIGURE 5.2. How disaster risk increases as risk components—hazard, exposure, and vulnerability—increase. Source: Adapted from World Bank (2013).

Of the many models for understanding vulnerability, the most useful in disaster risk management is the "holistic perspective" adopted by the IPCC's fourth assessment report (IPCC, 2012). This perspective keeps the focus on adaptive capacity—in other words, the ability of a system to adjust to climate change in order to moderate potential damage, take advantage of opportunities, or cope with the consequences (IPCC, 2007; IPCC, 2012).

There are two common factors that determines vulnerability both in climate change adaptation and disaster risk management communities (IPCC, 2012). The first one is susceptibility/fragility (in disaster risk management) or sensitivity (in climate change adaptation).[1] The second is a lack of resilience (in disaster risk management) or a lack of coping and adaptive capacities (in climate change adaptation).[2] Though the concept of resilience

1 It is defined as "physical predisposition of human beings, infrastructure, and environment to be affected by a dangerous phenomenon due to lack of resistance and predisposition of society and ecosystems to suffer harm as a consequence of intrinsic and context conditions making it plausible that such systems once impacted will collapse or experience major harm and damage due to the influence of a hazard event" IPCC (2012). Managing the risks of extreme events and disasters to advance climate change adaptation. A special report of working groups i and ii of the intergovernmental panel on climate change. C. B. Field, V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.). Cambridge, UK, and New York, NY, USA: 582 pp..

2 It is defined as "limitations in access to and mobilization of the resources of the human beings and their institutions, and incapacity to anticipate, adapt, and

is used in many different ways (de Bruijn et al., 2017), resilience is used in this chapter as "the ability of a system and its component parts to anticipate, absorb, accommodate or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration or improvement of its essential basic structures and functions" (IPCC, 2012). There are two primary approaches toward when to develop resilience. First, resilience can be accomplished *passively* after a disaster (Somers, 2009; Normandin et al., 2019) . This notion is called *passive resilience or recovery resilience*, which focuses on recovery and reconstruction (Boin and Van Eeten, 2013; Sudmeier-Rieux, 2014; Normandin et al., 2019). Second, resilience can be built *proactively* before a disaster by improving the capacity to cope with complex situations (Somers, 2009; Normandin et al., 2019). This is called *precursor resilience* or *transformational resilience*, which focuses on reducing risks and vulnerabilities (Boin and Van Eeten, 2013; Sudmeier-Rieux, 2014; Normandin et al., 2019).

To see how best to implement resilience policy, we need to understand how resilience relates to the performance of a system as it faces hazards, Figure 5.3 spells out the relationship schematically.

The vertical axis corresponds to an entity's performance (a company, community, or country, for example, whether measured by Gross Domestic Product (GDP), regional GDP, or sales or profits). The horizontal axis is a relative scale of time (daily, monthly, yearly, or any other relevant unit). Vulnerability becomes visible as the depth of decline in performance after a disaster occurs. Resilience shows up in the size of the lined area, which shows both depth of shock (i.e. vulnerability) and angle of recovery or reconstruction. The greater the area, the less the resilience—that is, it is an inverse relationship. This essentially means that resilience, in a simple sense, can be determined by a combination of degree of vulnerability and the speed of recovery and reconstruction.

This figure can reflect not just the given entity's individual resiliency, but vulnerabilities (and resilience) induced by interdependencies among administrations, sectors and in society in general (Normandin et al., 2019). That is:

1. Vulnerability to initial shock may be greater when a system has interdependent relationships with other systems also affected by the hazard.
2. The angle of recovery is affected by the recovery (or stability) of other systems affected by the hazard

The upshot of these observations is that the implementation of resilience

respond in absorbing the socio-ecological and economic impact" ibid.

policy requires collaborations in society that gather a wide range of public and private stakeholders, including citizen participation (Haraguchi, 2019; Normandin et al., 2019). More fundamentally, the societal level of resilience is dependent on the degree of resilience of each different level of society from sectoral community to individual organisations (Haraguchi et al., 2016).

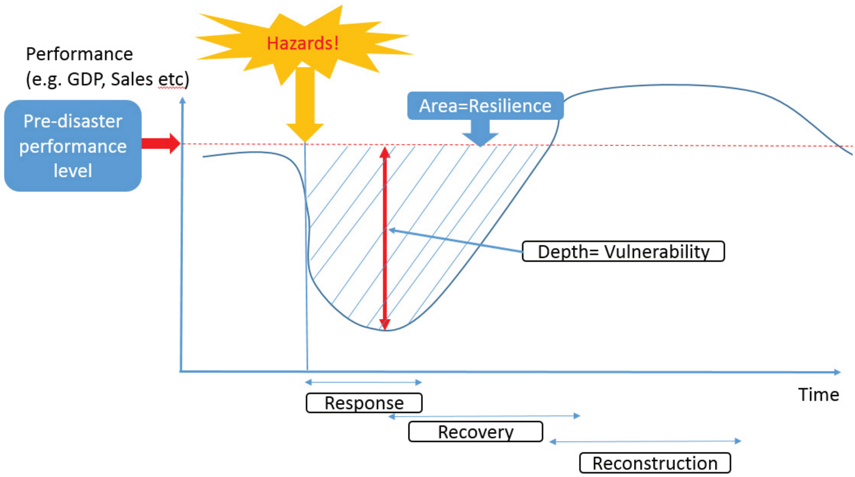

FIGURE 5.3. Conceptual picture of resilience and vulnerability

Assessing the Scale and Extent of Disaster

The type of extreme event involved determines which disaster risk factors are most impactful. In less extreme events—namely, higher occurrence probability, lower consequence—the vulnerability of a society plays a more important role. In contrast, in catastrophic events—low-probability, high consequence events—the intensity of hazards and exposures tends to cause more disaster loss than vulnerability does (IPCC, 2012).

Large-scale catastrophes tend to attract more popular and political attention. However, some studies have discovered that cumulative impacts from small, but recurrent disasters are sometimes more damaging for societies (Campos et al., 2012). For example, in Colombia between 1972 and 2012, cumulative losses from small disasters were 2.5 times greater than from large-scale disasters (World Bank, 2013).

Further, given the way advancements in information technologies and globalization have caused societies and critical infrastructure systems to become interdependent, it has become increasingly important when analysing disaster to consider systemic risk—that is, the risk across all connected systems. For example, the more interconnected global value chains become, the more likely economic losses are to increase (Haraguchi and Lall, 2015). One point of failure in the supply chain leads to the cascading failure of the entire system (Merz et al., 2014). For example, during the 2011 Japanese earthquake and Thailand floods, many factories located far from the affected regions had to reduce operations because of the stagnant sales and interrupted supply of parts. In addition, the more interconnected the critical infrastructure is, the greater the potential economic damages and losses (Kadri et al., 2014; Haraguchi and Kim, 2016). Failures in one sector will lead to failures in other sectors. A notable example is New York City in the aftermath of Hurricane Sandy (Haraguchi and Kim, 2016). The blackout in the electric grids caused inoperability in other critical infrastructure, such as wastewater treatment systems, hospitals, and building operations. The interconnected risks of critical system failures may result in catastrophic cascade effects due to functional interdependence or physical proximity. Heterogeneous networks, in general, are particularly vulnerable to attacks in that a large-scale cascade may be triggered by disabling a single key node (Motter and Lai, 2002). This interdependence is also enhanced by an increasing degree of economic integration. The economists Acemoglu et al. (2012) found that higher-order interconnections would lead to exactly such “cascade effects”, whereby shocks to one sector propagate not only to immediate downstream customers, but also to the rest of the economy.

Hazards, Exposure and Vulnerability Trends

Though it is challenging to identify, with high confidence, long-term changes in climate and weather extremes, data since 1950 provides evidence of significant changes in certain regions (IPCC, 2012). For example, statistically significant trends have emerged in the number of heavy precipitation events in some regions, and it is likely that more regions have experienced increases than decreases of rainfall (IPCC, 2012). These changes in hazard could affect occurrences of extreme weather and climate events.

Even as the hazard of extreme weather increases, it is highly likely that trends in exposure and vulnerability are primary drivers of changes in disaster risk (IPCC, 2012). IPCC (2012) claimed that exposure and vulnerability differ across temporal and spatial scales and depend on socioeconomic, demographic, institutional, and environmental factors. In particular, settlement patterns, urbanisation, and changes in socioeconomic conditions have already affected observed trends in exposure and vulnerability to extreme weather and climate events (IPCC, 2012). Uitto (1998) argued that the development of megacities with high population density, such as Shanghai and Bangkok, has increased the exposure of people to disaster risks because of rapid unplanned development. In particular, vulnerability is intertwined in a complex way with other socioeconomic factors, through susceptibility such as with the degree of interconnectedness of economy (Adger et al., 2009; Kleindorfer, 2009; Gassebner et al., 2010; Linnerooth-Bayer and Sjostedt, 2010).

Disaster Impacts and Socioeconomic Development Stages

As described, exposure and vulnerability are key determinants of disaster risk and of impacts when risk is realized (IPCC, 2012). Types of damages and losses differ depending on the stage of economic development. Historical trends of losses and mortality clearly show the interlinkage between disaster losses and development. Table 5.1 shows the 10 deadliest disaster events in the world between 1980 and 2010, while Table 5.2 shows 10 costliest events in the world for the same period. Fatalities are mostly concentrated in low-income and lower middle-income countries, which suffered 85% of total global disaster fatalities (Munich Re, 2013; Munich Re, 2013; World Bank, 2013). For example, the United Nations Development Programme (UNDP) estimated that 53% of fatalities due to droughts, earthquakes, floods, and windstorms occur in low-income countries whereas only 11% of people exposed to these hazards live in these underdeveloped countries (UNDP, 2004).

In contrast, the top 10 economic losses are concentrated in high-income countries (e.g., Japan, USA, Chile) and upper-middle countries (e.g., China, Thailand). However, the economic impact of disasters is largest in rapidly growing middle-income economies due to increasingly exposed assets (World Bank, 2013) . In these countries, the average impact of disasters was 1% of the GDP between 2001 and 2006, which is 10 times higher than the average in high-income economies during the same period (World Bank, 2013). Furthermore, proportionate impacts are larger in poorer countries, such as small islands and land-locked countries (World Bank, 2013). For example, in Dominica, the costs of the 2015 floods are equivalent to 96% of GDP; the 1998 storms cost over 100 of GDP in St. Kitts and Nevis; and in Grenada, the 2004 hurricane cost damages equivalent to 200% of GDP (Alleyne et al., 2017). During 1980–2010, in terms of human lives lost, low and low-to-middle income countries suffered 85% of total global disaster fatalities (Munich Re, 2013; Munich Re, 2013; World Bank, 2013). IPCC (2012) estimated that even future increases in economic losses due to climate extremes will be primarily driven by socioeconomic issues. Therefore, the role of developmental interventions is large.

TABLE 5.1. Top 10 deadliest disasters (1980–2013), ordered by fatalities

Date	Hazard	Affected Area	Overall losses in millions of USD (Original values)	Fatalities
12.1.2010	Earthquake	Haiti: Port-au-Prince, Pet-ionville, Jacmel, Carrefour, Leogane, Petit Goave, Gressier	8,000	222,570
26.12.2004	Earthquake, tsunamis	Sri Lanka, Indonesia, Thailand, India, Bangladesh, Myanmar, Maldives, Malaysia	10,000	220,000
2-5.5.2008	Cyclone Nargis, storm surge	Myanmar: Ayeyawaddy, Yangon, Bugalay, Rangun, Irrawaddy, Bago, Karen, Mon, Laputta; Haing Kyi	4,000	140,000
29-30.4.1991	Tropical cyclone, storm surge	Bangladesh: Gulf of Bengal, Cox's Bazar, Chittagong, Bola, Noakhali districts, esp. Kutubdia	3,000	139,000
8.10.2005	Earthquake	Pakistan, India, Afghanistan	5,200	88,000
12.5.2008	Earthquake	China: Sichuan, Mianyang, Beichuan, Wenchuan, Shifang, Chengdu, Guangyuan, Ngawa, Ya'an	85,000	84,000
July–Aug 2003	Heat wave	Europe, esp. France, Germany, Italy, Portugal, Romania, Spain, United Kingdom	13,800	70,000
July–Sept 2010	Heat wave	Russian Federation: Moscow region, Kolomna, Mokho-voye; Voronezh, Ramonskiy, Maslovka	400	56,000
20.6.1990	Earthquake	Iran: Caspian Sea, Gilan prov-ince, Manjil, Rudbar; Zanjan, Safid, Qazvin	7,100	40,000
26.12.2003	Earthquake	Iran: Bam	500	26,200

Source: Adapted from Munich Re (2014)

TABLE 5.2. Top 10 costliest disasters (1980–2013), ordered by overall losses

Date	Hazard	Affected Area	Overall losses in millions of USD original values	Fatalities
11.3.2011	Earthquake, tsunami	Japan: Honshu, Aomori, Tohoku; Miyagi, Sendai; Fukushima, Mito; Ibaraki; Tochigi, Utsunomiya	210,000	15,880
25–30.8.2005	Hurricane Katrina, storm surge	USA: LA, New Orleans, Slidell; MS, Biloxi, Pascagoula, Waveland, Gulfport; AL; FL	125,000	1,322

TABLE 5.2 (*continued*)

Date	Hazard	Affected Area	Overall losses in millions of USD original values	Fatalities
17.1.1995	Earthquake	Japan: Hyogo, Kobe, Osaka, Kyoto	100,000	6,430
12.5.2008	Earthquake	China: Sichuan, Mianyang, Beichuan, Wenchuan, Shifang, Chengdu, Guangyuan, Ngawa, Ya'an	85,000	84,000
24–31.10.2012	Hurricane Sandy, storm surge	Bahamas, Cuba, Dominican Republic, Haiti, Jamaica, Puerto Rico, USA, Canada	68,500	210
17.1.1994	Earthquake	USA: CA, Northridge, Los Angeles, San Fernando Valley, Ventura, Orange	44,000	61
1.8–15.11.2011	Floods	Thailand: Phichit, Nakhon Sawan, Phra Nakhon Si Ayuttaya, Pathumthani, Nonthaburi, Bangkok	43,000	813
6–14.9.2008	Hurricane Ike	USA, Cuba, Haiti, Dominican Republic, Turks and Caicos Islands, Bahamas	38,000	170
May–Sept 1998	Floods	China: Yangtze, Songhua Jiang	30,700	4,160
27.2.2010	Earthquake, tsunami	Chile: Bió Bió, Concepción, Talcahuano, Coronel, Dichato, Chillán; Del Maule, Talca, Curicó	30,000	520

Source: Adapted from Munich Re (2014)

Disasters, Poverty, and Marginalized Population

Disasters disproportionally affect poor and marginalized populations. Because the poor have limited assets and resources, they are likely to face greater risks by living and working in risky areas. For example, during catastrophic floods in the Greater Accra Metropolitan Area, poorer households lost less than their richer households in absolute terms, but poorer households lost more in terms relative to their annual expenditure than richer households did (Erman et al., 2018). Among the poor, marginalized people such as the elderly, the disabled, orphans, and widows have a greater vulnerability to disasters (World Bank, 2013). For example, 91% of fatalities from Cyclone Gorky in Bangladesh in 1991 were women (World Bank, 2013). Meanwhile, 49% of victims of Hurricane Katrina in Louisiana in the

US were 75 years old or older (Brunkard et al., 2008). Disasters sometimes exacerbate poverty by increasing risk for the poor. For example, in Banda Ache, Indonesia, McCaughey et al. (2018) discovered that the price of inland properties increased after a tsunami in 2004 because many tsunami survivors and newcomers to the affected area preferred to live farther from areas exposed to tsunami. However, the reconstruction plan only allowed rebuilding in-place, which has had negative consequences. Since only a part of aid houses are occupied, both low-income tsunami survivors and poorer new comers disproportionally live in areas highly exposed to coastal hazards. This has created socioeconomic segregation, which had never existed before the tsunami (McCaughey et al., 2018). Thus, providing reconstruction aid predominantly within areas exposed to the hazard can negligently transfer risk to the poor (McCaughey et al., 2018).

Disasters, Sustainable Development and Climate Change

Disasters, Development, and Climate Change

Climate change, disaster risks, and development are interrelated. A high degree of vulnerability and exposure is primarily caused by poor developmental practices, such as rapid demographic changes, environmental mismanagement, and rapid and unplanned urbanisation (Sanchez-Rodriguez et al., 2005; Cannon, 2006; Cardona, 2011; Maskrey, 2011; IPCC, 2012). Disaster risk, development, and climate are closely linked, as shown in Figure 5.4.

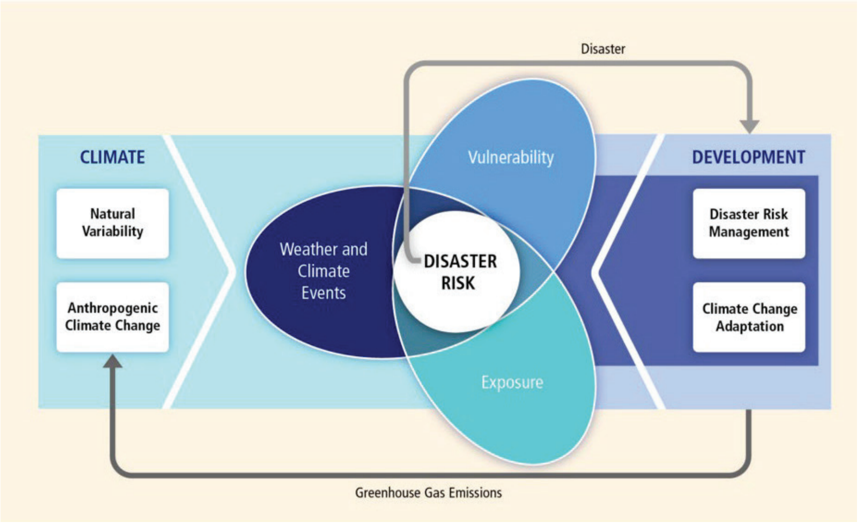

FIGURE 5.4. Interlinkage among climate, disaster risk, and development. Source: Adapted from IPCC (2012).

Disasters slow down development and destroy physical infrastructures or worsen development processes. Recovery from, and reconstruction following, a disaster, along with disaster risk reduction, require development investment, which in turn requires energy. If energy is not clean energy, development investment with energy consumption leads to a large amount of greenhouse gas emissions (GHGs). Increases in GHGs' concentrations in the atmosphere lead to anthropogenic climate change, which—over the long term—is projected to increase the frequency and intensity of natural hazards. Increases in natural hazards will lead to increases in disaster risks without the proper management of exposure and vulnerability. Therefore, the proper management of disaster risk is directly critical for development processes, but also indirectly essential for addressing climate change.

Climate change affects disaster risks in two ways. First, short-term climate variability and its extremes directly affect the magnitudes and frequency of hazards and the shocks with which society has to cope (Schipper and Pelling, 2006). IPCC (2012) estimates that in the long-term (more than 40 years) tropical cyclone activity will increase (with low confidence) whereas droughts will become more intense and longer in southern Europe and West Africa (with medium confidence). Because of these changes, unprecedented extreme weather and climate events might occur. Second, longer-term changes in climate will influence productive activities, assets, and capitals of society, particularly in natural resource-dependent economies (Schipper and Pelling, 2006). If society's productivity, such as in an agricultural economy, or social capitals deteriorate due to climate change, the society might become more vulnerable to natural hazards, which a stronger economy could help manage (Schipper and Pelling, 2006). In this case, long-term change in climate negatively affects society's coping capacity, which leads to an increase in disaster risk.

Conversely, because climate change and DRM are interlinked, the successful mitigation of anthropogenic climate change can mitigate disaster risk in both direct and indirect ways. Direct influence comes from reducing weather-related uncertainty and hazards and from lessening asset depletion in natural resource-dependent societies (Schipper and Pelling, 2006). Indirectly, effective mitigation will increase asset availability that can be allocated for mitigating disaster risks and building resilience (Schipper and Pelling, 2006).

Whilst climate change actions and disaster risk management are distinct issues, there are a number of overlaps and common elements. For example, the most effective way of simultaneously addressing climate change adaptation and disaster risk management is to reduce vulnerability (Schipper and Pelling, 2006; Mechler et al., 2014). Also, the knowledge of climate-related disaster risk management can enhance the understanding and actions in international climate change negotiations on Loss and Damage Mechanisms. The mechanism is the main apparatus under the UN Climate Convention for dealing with irreversible losses and costly damages caused by climate change, which are considered beyond the adaptability ability of countries (Mechler et al., 2014; Gewirtzman et al., 2018).

The Role of Decadal to Centennial Scale Climate Variability

The significant attention to climate change impacts in recent years has to an extent masked the important role of quasi-periodic decadal to centennial scale climate variability on climate extremes and hence on the space and time clustering of climate risk (Sarachik et al., 1996; Hulme et al., 1999; Delworth and Mann, 2000; Solomon et al., 2011). The role of El Nino on contemporaneous floods and droughts around the world is well recognized, as is the role of the North Atlantic Oscillation (decadal), Pacific Decadal Oscillation, the Indian Ocean Dipole, Inter-Pacific Oscillation and the Atlantic Multidecadal Oscillation (Dilley and Heyman, 1995; Mann et al., 1995; Kleeman et al., 1999). The interactions across these modes translate into persistent climate extremes across many global regions, which pose a significant challenge for system resilience (Diaz and Pulwarty, 1997; Stahle and Dean, 2011; Malherbe et al., 2016). The general increase in the frequency of extremes due to climate change does not usually account for how these persistent climate risks may change, primarily because the climate models do not yet reliably reproduce these natural climate variations and their space and time expression in retrospective analyses. Consequently, while the IPCC projections do not account for the role of such climate variations, from the perspective of resilience to disasters, it is very important to go beyond the IPCC projections and develop a statistical understanding of the spatial expression and temporal predictability of these natural modes of long term climate variability. There is emerging evidence that using paleoclimate data and modern statistical and machine learning models, as well as climate models, some aspects of decadal climate variations are predictable and may hence have utility for disaster risk prediction and management (Kwon et al., 2007; Nowak et al., 2011; Solomon et al., 2011; Karamperidou et al., 2014; Meehl et al., 2014; Wittenberg et al., 2014; Erkyihun et al., 2016; Srivastava and DelSole, 2017; Zhang and Kirtman, 2019).

Disaster Risk Management and the Sustainable Development Goals

Disaster risk management and Sustainable Development Goals (SDGs) are closely linked (Table 5.3). Even for SDGs' predecessor, Millennium Development Goals (MDGs), disaster risk was considered an important cross-cutting issue affecting the chances of meeting the goals (Pelling, 2003). For SDGs, UNISDR (2015) listed the linkage between each goal and DRM.

Hazards, exposure, and vulnerability are amplified or weakened by development issues targeted by SDGs:

- Effective disaster risk education (Goal 4), including emergency evacuation drills, reduces vulnerability (Muttarak and Lutz, 2014). In Nepal, more education has led to a reduced number of human and animal deaths as well as a decreased probability of households being affected during floods and landslides (KC, 2013).
- Anthropogenic climate change (Goal 13) would magnify weather-related disaster risk (King, 2004; Milly et al., 2008; Knutson et al., 2010), and increase costs of disasters (IPCC, 2012). For example, the risk of river floods will increase regionally within the next 20 years (Jongman et al., 2012; Hirabayashi et al., 2013; Willner et al., 2018). In the Caribbean, anthropogenic climate change is projected to increase annual losses caused by disasters by US$ 1.4 billion by 2050 (UNIDR, 2013). In the next 20 years, the total economic losses due to fluvial floods will increase by 17% globally (Willner et al., 2018). However, proper climate adaption would help mitigate disaster risks (Schipper and Pelling, 2006). Decadal to Centennial Scale Climate variability and predictability provides an opportunity for increasing early warning and system resilience. Strengthening in situ and remotely-sensed earth and climate observation will contribute to disaster risk reduction as well as climate adaptation (Haraguchi et al., 2019).
- Biodiversity deterioration in ecosystems (Goal 15) can reduce social-ecological resilience in coastal areas, thereby leading to hazards in coastal area disasters damaging communities (Adger et al., 2005).

On the other hand, disaster impacts would undermine the sustainable development agenda:

- Disasters, particularly slow onset disasters such as droughts, cause global food insecurity and hunger (Goal 2) (Shepherd et al., 2013).
- Disasters affect education in two ways (World Bank, 2017). First, disasters destroy the educational infrastructure. For instance, in China, more than 7,000 schools were destroyed by the 2008 Wenchuan earthquake (World Bank, 2017). Second, following disasters, children from poor households have to drop out of school to work in order to compensate the economic losses caused by disasters. In Nicaragua, child labour increased by 58% in disaster-affected areas (World Bank, 2017).

TABLE 5.3. Linkage between SDGs and DRM

SDGs	Examples of SDG's relationship to disaster risks
Goal 1: No Poverty	Poverty increases vulnerabilities. Disasters negatively exacerbate poverty (McCaughey et al. 2018).
Goal 2: Zero Hunger	Disaster causes global food insecurity and hunger (Twigg 2004; Shepherd et al. 2013).
Goal 3: Good Health and Well-being	Disasters affect people's health and well-being, including psychiatric disorders, generalized distress, physical illness, and interpersonal problems (Norris et al. 2002; Norris et al. 2002).
Goal 4: Quality Education	Education reduces vulnerability to disasters (KC 2013; Muttarak and Lutz 2014). Resilient school structures serve as a hub for emergency response and evacuation during disasters.
Goal 5: Gender Equality	Women and girls are more exposed to disaster risks than men (Schipper and Pelling 2006). Women can reduce disaster risks.
Goal 6: Clean Water and Sanitation	Water-related disasters account for 90% of the 1000 most fatal natural disasters between 1900 and 2006 (Adikari et al, 2009).
Goal 7: Affordable and Clean Energy	Disasters destroy energy infrastructure (UNISDR 2015).
Goal 8: Decent Work and Economic growth	The impacts of disasters on economic assets, capital and infrastructure have negative effects on employment, economic activity, and growth for many years after a disaster event (Overseas Development Institute and World Bank Group 2015).
Goal 9: Industry, Innovation, and Infrastructure	Disasters will destroy lifelines and infrastructures (Kobayashi 2014; Urlainis et al. 2014). Structural and non-structural measures are critical.
Goal 10: Reduced Inequality	Disasters would exacerbate social inequalities (McCaughey et al. 2018).
Goal 11: Sustainable Cities and Communities	Urbanisation will increase population exposed to hazards (Dodman et al. 2017). By 2050, the urban population exposed to cyclone in the world will increase from 310 million to 680 million by 2050, whereras that to earthquake will increase from 370 million to 870 million (World Bank 2013; UNISDR 2015).
Goal 12: Responsible Consumption and Production	Improper dumping of waste may cause flooding (UNISDR, 2015). Debris is generated from destroyed buildings and infrastructures after disasters, causing the delay of recovery (Brown et al. 2011).
Goal 13: Climate Action	Climate change magnifies weather-related disaster risk (King 2004; Milly et al. 2008; Knutson et al. 2010) and increases costs of disasters. Climate adaption will help disaster risk mitigation.
Goal 14: Life Below Water (Ocean)	More and more people will live in coastal areas.
Goal 15: Life on Land (Ecosystem)	Ecosystem degradation leads to higher exposure (Adger et al. 2005).
Goal 16: Peace, Justice, and Strong Institutions	Disasters and conflict are mutually reinforcing (UNISDR 2015).
Goal 17: Partnerships for the Goals	Both SDGs and DRM require partnerships, and DRM requires resilience in multilevel in society (Haraguchi et al. 2016).

Source: Goverment office for Science (2012)

- Disasters also affect people's health (Goal 3), both physical and mental, as well as their well-being. The effect of temporary malnutrition in childhood associated with the aftermath of disasters would undermine lifelong health, stunting growth and lowering cognitive abilities (World Bank, 2017). In rural Zimbabwe, children aged 12 to 24 months lost 1.5–2 centimetres of growth during a drought (John and Bill, 2001). Furthermore, even 16 years after the 1982–1984 drought in Zimbabwe, children who suffered from stunted growth during the disaster still underperformed in school (World Bank, 2017). In addition, post-traumatic stress disorder gets less attention, and post-disaster support for this disorder is in high demand (Kokai et al., 2004).

- Disasters also destroy critical energy infrastructures (Goal 7) and resilient infrastructures (Goal 9) (Urlainis et al., 2014).

Determinants of hazards, particularly exposure and vulnerability, are closely influenced by socioeconomic factors in development. Hence, by pursuing a sustainable development agenda, disaster risks can be mitigated. Regarding this, Adger et al. (2005) offered a notable example in Bangladesh. In 1991, a powerful category 5 tropical cyclone resulted in more than 100,000 fatalities and forced the displacement of millions of people in Bangladesh, yet the same size hurricane, Hurricane Andrew, resulted in only 23 deaths. The primary cause of the fatalities in Bangladesh was a lack of social resilience (Adger et al., 2005). In the past decade, Bangladesh has managed to enhance its resilience and drastically reduced mortalities caused by tropical cyclones and flooding (Adger et al., 2005).

Disaster Risk Management

Options for Risk Management

Humanitarian relief is critical for saving lives after a catastrophe and recovering quickly; however, it can be distorted and used as a preferred strategy for risk management over long-term risk reduction (Schipper and Pelling, 2006). This kind of moral hazard, called the "Samaritan's dilemma," describes a situation when the funding of disaster relief and reconstruction can disincentivize governments to invest in long-standing disaster risk reduction efforts (Anderson and Woodrow, 1998; Wisner, 2001; Schipper and Pelling, 2006). This kind of moral hazard has been observed in several cases throughout the world, such as El Salvador (Wisner, 2001). In this sense, proper ex-ante risk management is needed to reduce the degree of necessity for humanitarian relief. Four strategies can be used to deal with disaster risks: risk avoidance, risk retention, risk mitigation, and risk transfer (Table 5.4).

Dealing with Uncertainties: Co-benefit and No-regret Strategies

Each phase of disaster risk management embodies multiple uncertainties. For example, during the reconstruction, reduction, and prevention phases, investment has to be made under uncertainty, which means that policymakers have to make investment decisions for future disasters that may not occur soon—or ever—during the investment time frame. To deal with these types of uncertainties, there are main two practical strategies to policy interventions.

TABLE 5.4. Risk Management Options

Options for risk management	Definition	Example
Risk avoidance	To simply change circumstances so that the risk no longer exists.	Retrieve settlement from risky coastal areas or a volcano.
Risk mitigation	To reduce their exposure or vulnerability or to increase resilience so that the likelihood or magnitude of an impact caused by the risk decreases or the recovery after the impact is enhanced.	Build disaster-resilient infrastructures, such as dikes or levees.
Risk retention	To accept risks and manage dealing with the impact caused by risks.	Store financial resources in reserve in case of disasters.
Risk transfer	To use a mechanism to share part or all of the risks with another entity better positioned to take on the risk.	Insurance and Cat Bond mechanisms

Source: Government Office for Science (2012)

The first strategy is the co-benefit approach (Lavell and Maskrey, 2014), which is a win–win strategy aimed at capturing both DRM and development benefits in a single policy intervention. This strategy is designed to reduce DRM-related vulnerability while also generating corollary benefits that do not directly contribute to disaster risk reduction (Table 5.5). Following this strategy, public infrastructure should be built to fulfil multiple purposes—namely, to reduce disaster risks while serving other development goals during non-disaster periods. Because it is hard to predict when a large catastrophe will occur, it is challenging to justify the cost-benefit ratio for public investment in large-scale infrastructure for disaster risk management if a benefit is only to mitigate disaster risks. However, accounting for other benefits as a co-benefit leads to improving cost–benefit ratios. For example, during the 2011 Great East Japan Earthquake, known as the Fukushima Earthquake, roads and expressways protected against tsunamis and flooding, and served as evacuation places or base sites for emergency response operations (Ranghieri and Ishiwatari, 2014). These co-benefits should be considered in any cost–benefit analysis of a project.

TABLE 5.5. Examples of Co-benefits between DRM benefits and Other Development Benefits

Case	DRM Benefits	Other benefits	Description
Tsunami dike during the 2011 Great East Japan Earthquake in Kamaishi Japan (Ranghieri and Ishiwatari 2014)	Structural measures to prevent tsunami penetration	Transportation route	Transportation routes such as road and railway during non-disaster times worked as a preventive tsunami wall during the earthquake and tsunami.
Super-levees in the Arakawa River in Tokyo Japan (World Bank 2017)	River flood management	Restoration and revitalization of riverbeds, wildland conservation, and building residential areas	A super levee is a river embankment with 10-meters height and 300-meters width. The levees prevent a catastrophic river floods. The levees allow for constructing commercial and residential areas on the embankment and redesigning waterfront to restore and revitalize riverbeds and conserve wildlands.
Citizen involvement during the 1995 Kobe Earthquake in Kobe Japan (Shaw 2014)	Quick rescue and recovery	Development of social welfare community	Daily community development promoted the social bonding in community. Community members rescued neighbors and contributed to the consensus building during the recovery and reconstruction from the earthquake.
Yokohama stadium - Multipurpose retarding basin in Yokohama Japan (World Bank 2017)	River flood management	Sport stadium	During flooding, the structure of a sport stadium in Yokohama will serve as a retarding basin to store over 1.5 million cubic meters of flooded water.
Coastal structure in Sri Lanka (Samarasekara et al. 2017)	Protection against Storm surge and tsunami	Revetment, road, and railway embankment	The function of mitigating damages by tsunamis can be co-benefit functions for the main functions of providing physical protection (e.g., revetment) or socioeconomic functions (e.g., road and railway embankment)

Another strategy is a no-regret policy, which refers to a strategy that meets development needs regardless of the occurrence of disasters. In terms of economic efficiency, a no-regret policy reduces vulnerability when non-DRM benefits exceed the costs of implementation (Hallegatte, 2009). An example would be reducing the leakage rates of the water supply, which generates benefits on a daily basis while also reducing the vulnerability of the water supply sector to droughts. In this sense, this strategy faces few trade-offs.

Risk Financing

Risk-sharing and risk-transferring mechanisms, such as from households to governments or from governments to capital markets, are key for increasing resilience to disasters (IPCC, 2012; World Bank, 2013; Jongman et al., 2014), and ultimately to climate change (Mills, 2005). Disaster risk finance should be multi-layered depending on the consequences and frequencies of disasters (Figure 5.5). For high frequency and low consequence disasters, government reserves and contingency funds might be sufficient for governments to manage the impacts. However, middle frequency and middle consequence disasters require government reserves and contingency funds, contingent loans and credits, and insurance in addition to basic government reserves and contingency funds. For low frequency and high consequence disasters, all financial schemes, including international

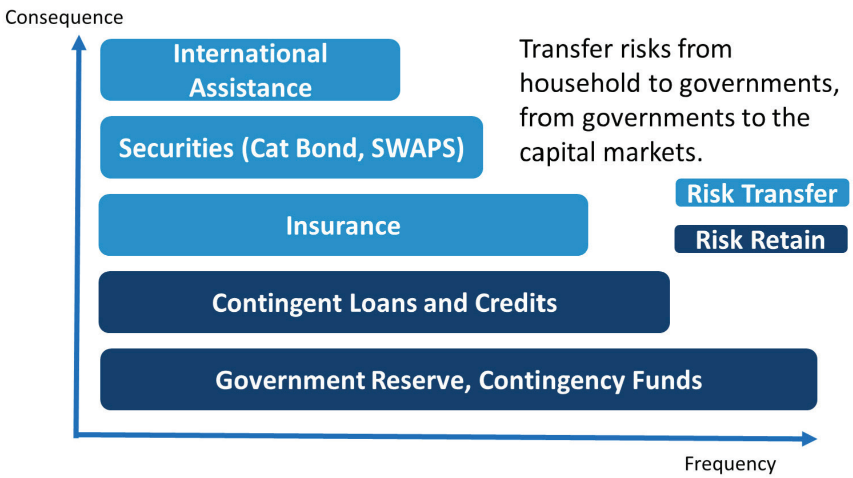

FIGURE 5.5. Risk-financing schemes for disaster risk management. Source: World Bank (2013)

TABLE 5.6. Sovereign catastrophe risk pools in the world

Facility	Caribbean Catastrophe Risk Insurance Facility (CCRIF)	Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI).	African Risk Capacity (ARC)	Southeast Asia Disaster Risk Insurance Facility (SEADRIF)
Year of establishment	2007	2014	2013	2018
Covered Hazards	Earthquakes, tropical cyclones, and excess rainfalls	Earthquake, tropical cyclone, extreme rainfall	Drought, tropical cyclone, flood	First product is a pool for flood risks.

TABLE 5.6. (*continued*)

Facility	Caribbean Catastrophe Risk Insurance Facility (CCRIF)	Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI).	African Risk Capacity (ARC)	Southeast Asia Disaster Risk Insurance Facility (SEADRIF)
Member countries	17 countries (Anguilla, Antigua & Barbuda, Bahamas, Barbados, Belize, Bermuda, Cayman Islands, Dominica, Grenada, Haiti, Jamaica, Nicaragua, St. Kitts & Nevis, St. Lucia, St. Vincent & the Grenadines, Trinidad & Tobago, Turks & Caicos Islands)	5 countries(Marshall Islands, Samoa, Tonga, Cook Islands, Vanuatu)	6 countries (Burkina Faso, Niger, Mali, Senegal, Mauritania, The Gambia)	Cambodia, Indonesia, Japan, Lao PDR, Myanmar, and Singapore
Total Payouts since the inception	US$ 120 million1	US$ 3.2 million2	US$ 34 million 2	No payout yet as of January 15 2019
Payout examples	Dominica received a payout of US$ 19 million within 14 days after the passage of Hurricane Maria in 2017.	Tonga received a US$ 1.27 million payout after Cyclone Ian in January 2014. Vanuatu received a nearly US$ 2 million payout seven days after tropical Cyclone Pam in March 2015.	Malawi received a payout of US$ 8.1 million to respond to the drought which resulted from the poor 2015 – 2016 agricultural seasons.	n/a

Note: 1: As of September 2017, 2: As of December 2016.

Source: World Bank (2017; 2018). Note 1: As of September 2017, 2: As of December 2016

assistance from donors, might be required. Government reserves, contingency funds, contingent loans, and credits are categorized as risk retaining in nature; in contrast, international assistance, securities and swaps such as catastrophe bonds (Cat Bonds or CAT), and insurance are risk-transferring mechadnisms.

An emerging trend in disaster financing is parametric (index) risk transfer (Haraguchi et al., 2016; Haraguchi et al., 2018). Parametric (index) risk transfer is a mechanism to provide immediate payouts based on a predetermined index, such as rainfall level, wind speed, and storm surge levels, rather than actual losses (Haraguchi et al., 2018). For agriculture and rural areas, index insurance policies have been sold in various countries, including Mexico, India, Malawi, and Ethiopia (Barnett and Mahul, 2007). In addition, index insurance for floods targeting farmers and microfinance intermediaries has been sold in some countries such as Vietnam and Peru (Khalil et al., 2007; Collier and Skees, 2012). However, at the national level, parametric insurance for disasters has not been implemented on a large scale for governments, although research has been conducted (Haraguchi et al., 2018).

Among disaster risk financing schemes shown in Figure 5.5, a risk-sharing pool for multiple countries is a new, innovative mechanism based on parametric indices. For example, the Caribbean Catastrophe Risk Insurance Facility (CCRIF) was established in 2007 as the first multi-country risk pool in the world; as of June 2018, it serves 17 Caribbean countries. The facility helps member countries deal with the short-term cash problems after major natural disasters, focusing on earthquakes, tropical cyclones, and excess rainfall. Since its inception in 2007, the facility's total pay-out has been 36 to 13-member countries, totalling US$130.5 million. Similar types of risk pools are listed in Table 5.6.

Conclusions

This chapter has introduced the fundamentals of disaster risk management in the context of sustainable development. Historically, the number of fatalities due to disasters is declining, while the numbers of disasters, people affected, and economic losses are rising. Economic losses due to weather- and climate-related disasters have increased, though large spatial and interannual variability exists. The impacts of extreme events are highly correlated with the degree of society's exposure and vulnerability, which are closely linked with the status of socioeconomic development of society.

Each component of disaster risk, namely hazards, exposure, and vulnerability, dynamically determines risks, depending on socioeconomic development levels of society and types of extreme events. Resilience is also closely linked with vulnerability, though it is used in many different ways. In addition, emerging agenda in DRM is the concept of an interdependent risk or systemic risk. The impacts of disaster have propagated through interconnected infrastructure, transportation, economic, and supply chain systems. Some significant changes in hazards have been observed, depending on regions in the world and types of hazards. Shifts in exposure, such as urbanisation and changes in settlement patterns, and vulnerability have influenced changes in disaster risks.

Types of damages and losses are distinct depending on the stage of development. Fatalities due to disasters are concentrated in low-income and lower-middle-income countries. Economic losses in absolute terms are concentrated in high-income countries and upper-middle income countries, while the economic impact in relation to the size of economies is highest in small island and land-locked developing countries. Finally, disasters affect disproportionately the poor. Even improper reconstruction aid can create socioeconomic segregation, which has never existed before a disaster hits, and indifferently transfer risk to the poor.

This chapter emphasizes that DRM and sustainable development agendas are closely linked and that DRM is a critical factor for achieving various goals of SDGs. Pursuing sustainable development adequately will help countries reduce disaster risks in the long-term. Because climate change, disaster, and development issues are interlinked as shown in Figure 5.4, the proper disaster risk management is required directly for development as well as indirectly for addressing climate change. Furthermore, the effective mitigation of anthropogenic climate change can lessen disaster risk by reducing the magnitude and frequency of hazards and protecting productive activities and assets.

To manage long-term uncertainties in implementing DRM policies, co-benefit and no-regret strategies are effective. A co-benefit strategy is designed to address both DRM and other development gains in a single policy intervention. In contrast, the no-regret approach is designed to meet development needs even if a disaster would not occur in the future. These strategies would give countries incentives to mainstream disaster risks into economic planning and investment decisions. Furthermore, an innovative parametric risk transfer and multilateral risk-sharing pool are needed to manage residual risks and bring about transformative changes in investment in DRM. With adequate policy intervention and the advancement of science and technology, investment in proper risk management will yield a stable dividend.

We emphasize the importance of also focusing on decadal and longer natural climate variability to address resilience in disaster risk management, though we acknowledge the importance of climate change in changing the risk profile for climate induced disasters. This is identified as an area with potential gains in risk anticipation and management but is inadequately researched and understood at this point.

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