Chapter 1

Food Security in the Face of Disaster and Climate Change: Adaptation Roadmap

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CHAPTER 1

Food Security in the Face of Disasters and Climate Change

ADAPTATION ROADMAP

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ABSTRACT

It is clear that climate change and recurrent natural disasters have a serious impact on food security. Given the high likelihood of further climate variabilities and extreme weather events, and resultant potential impacts on food security, it is essential to address adaptation strategies for food security. Adaptation strategies must be implemented to improve the productivity of agriculture under the existing state of climate change to improve future variability, while meeting growing demands for food security. The objectives of this chapter are to outline the impacts of natural disasters and climate change on food security, and to suggest adaptation strategies that can help manage risks and achieve resilience. Achieving an adaptation action plan will require the integration of disaster risk management and climate change-related issues with other risk factors. This information will help policymakers make decisions to address the impacts of natural disasters and climate change, and achieve food security.

1.1 Introduction

Reducing risks to food security from natural disasters and climate change is one of the foremost challenges of the 21st century. The effects of natural disasters and climate change threaten agriculture by decreasing the production of crops, fisheries, and livestock (Food and Agriculture Organization [FAO], 2016). About 60% of the Earth's surface is occupied by croplands, pastures, and forests; and these are gradually being exposed to threats from increased climatic variability. Unusual changes in temperature and rainfall patterns lead to more frequent droughts and floods, which have long-term effects on ecosystems. The increased intensity and occurrence of storms, droughts, flooding, and precipitation variance also impact food security.

Food security is a situation in which all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life (FAO, 1996). The four main components of food security are availability, access, utilisation, and stability (FAO, 2009). Several factors influence food security, such as population growth leading to elevated food demand, higher commodity prices, and resource degradation, as well as climate change and natural disasters. More than 80% of those who are food insecure live in countries prone to natural hazards and climate change, and derive their livelihood from agriculture while having a significantly low asset base (FAO, 2015).

Natural disasters and climate change are major risks for long-term food security, and have devastating impacts at the household level. Natural disasters, including droughts, storms, tsunamis, earthquakes, landslides, and floods can occur anytime anywhere, affecting food security and human life. Over the last decade, natural disasters caused $1.3 trillion in damages and affected over 2.7 billion people. Agriculture accounted for 23% of the damage caused by natural disasters from 2005 to 2014. Disasters like flash floods can cause crop, human, and economic losses in minutes, while prolonged droughts can destroy livelihoods more slowly. Agriculture is the main sector affected by drought, accounting for about 84% of the total economic impact (FAO, 2018). Natural disasters limit the capacity of food production by affecting crop yields, seed reserves, livestock, fisheries, farm equipment, infrastructure, supply systems, and food trade, resulting in economic losses and disrupting the internal equilibrium in vulnerable nations (De Haen, 2008; Sperling, 2008).

Climate change poses additional challenges to food security. More extreme temperatures and precipitation due to climate change affect agricultural productivity by facilitating the spread of pests and diseases, decreasing the efficiency of crop-water use, and reducing the nutrient content of crops, in turn affecting household income and food security (Wheeler and von Braun, 2013). Simultaneously, sea-level rise directly causes flooding, salinisation, and increased groundwater salinity, threatening food production. Agricultural production in the developing countries of Asia and Africa is adversely affected by climate change, putting the livelihoods of large numbers of the rural poor at risk and further increasing their vulnerability to food insecurity by affecting aquatic life (by influencing reproduction and migration timings). Climate change has the potential to affect food security at the global, national, and local levels by disrupting food availability, access to food, and food quality. Extreme weather events can affect food access by impacting transport and food distribution, both locally and globally. The climate is a highly important driver of the food supply chain from production to consumption; this is especially true at the production level, as it affects the quantities and types of food produced and the adequacy of production-related income. Extreme weather events can damage or destroy transport and distribution infrastructure and adversely affect other nonagricultural parts of the food system (FAO, 2015).

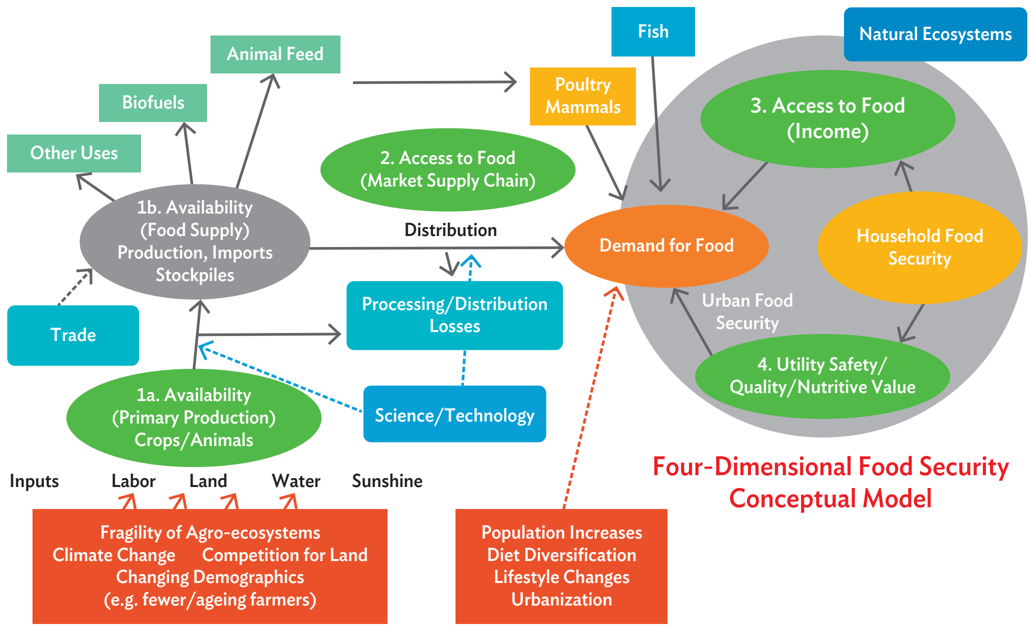
Given the inevitability of natural disasters and climate change impacting agricultural systems, adaptation is necessary to maintain future food security. More studies are required to incorporate multiple systems and interests in adaptation, and formulate a response to the imminent threat to the food system. Adaptation strategies that manage disaster risk reduction and face climate-related extreme weather events aim to diminish the factors that contribute to these risks, and subsequently to support and promote food security (Wheeler and Braun, 2013). Adaptation to climate change includes changes in socioeconomic systems to reduce their vulnerability both to the long-term impacts of climate change and to extreme climatic events. Extreme weather-related events are hazardous to food security and often exceed the capacity of a country or community to cope. The development of adaptation strategies to respond to the effects of disasters and climate change will require cooperation at the local, regional, and global levels, across disciplinary boundaries, and between different sectors of the economy. Improving the ability of communities to adapt to climate change and manage disaster risks requires addressing vulnerabilities at the local level, involving stakeholders, and ensuring that adaptation initiatives are compatible with existing decision processes (Brooks and Kelly, 2005).
In this chapter, we discuss natural disasters and climate change impacts on agricultural production and food security. Ensuring food security and adaptation are ways to mitigate

the negative effects of climate change. We also discuss adaptation strategies, outlining core principles, priority actions, and the implementation of proposals to achieve food security in the contexts of the Association of Southeast Asian Nations (ASEAN) and of the wider world.

1.2 Food Security and Effects of Natural Disasters

Food security fundamentally deals with the continuous availability of and access to food for people in appropriate quantities and quality to meet dietary requirements (Pinstrup-Andersen, 2009). There are four significant pillars of food security that are crucial to achieving sustainability: availability, access, utilisation, and stability over time. Food security initiatives focus on one or some combination of these pillars (Figure 1.1). Many factors, including natural disasters, extreme weather events due to climate change, a growing global population, land degradation, lack of water resources, rising food prices, and environmental stressors, have significant impacts on food security (Premanandh, 2011).

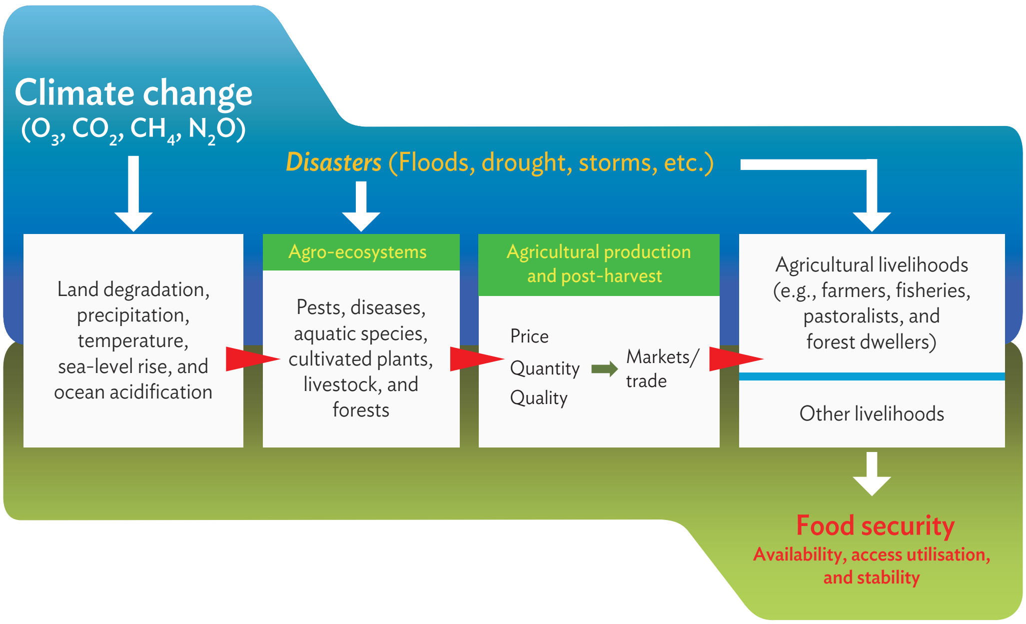
Figure 1.1: Food Security and its Components



Source: Teng, P. (2013), 'Food Security: Challenges and Opportunities for Collaboration', Presentation given during the Symposium on Metro Agriculture and Urban Food Security: An Explicative Symposium with Global Innoversity, 5 September; Desker, B., M. Caballero-Anthony, and P. Teng (2014), *ASEAN Food Security: Towards a More Comprehensive Framework* (No. PB-2014-03).

A natural disaster is any natural process or phenomenon that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage (United Nations International Strategy for Disaster Reduction [UNISDR], 2009). Natural disasters can be biological, geophysical, meteorological, climatological, and/or hydrological. Major factors that contribute to the intensification of the severity and frequency of natural disasters are climate change, urbanisation, and environmental degradation. The frequency and severity of droughts, floods, storms, and other disasters triggered by climate change have increased since the 1980s, causing severe agricultural losses in several developing countries and placing them at risk of food insecurity. Crop yield losses lower the availability of food commodities in local markets, leading to food inflation and reducing households' purchasing capacity. This restricts access to food, reduces savings, and may lead to the sale of vital productive assets, thus destroying livelihoods (UNISDR, 2015). Eventually, this leads to a reduction in the quantity and quality of food for consumption, resulting in food insecurity and malnutrition, especially amongst the most vulnerable (Figure 1.2).

Figure 1.2: Overview of Impacts of Natural Disasters and Climate Change on Food Security

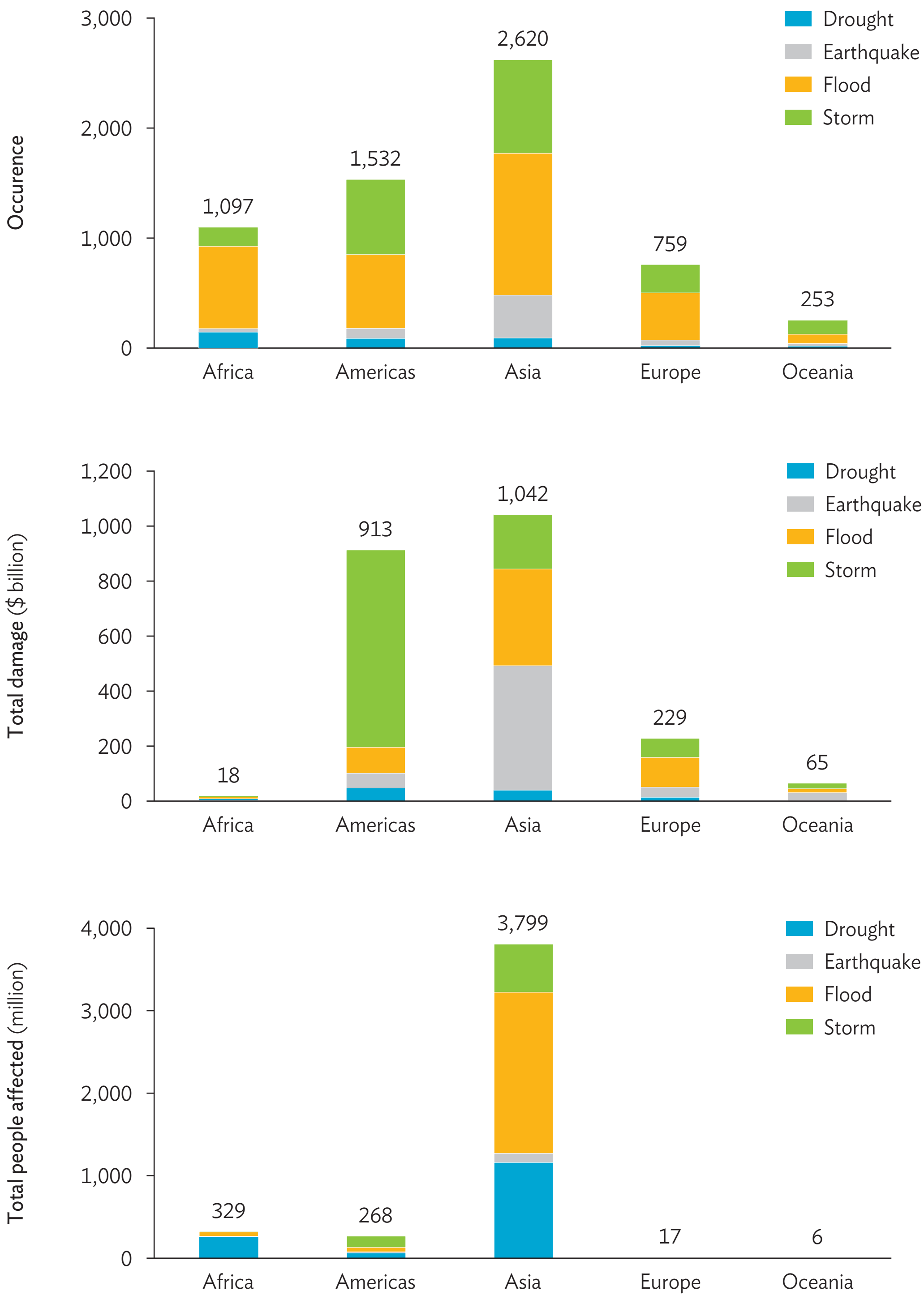


CH_4 = methane, CO_2 = carbon dioxide, N_2O = nitrous oxide, O_3 = ozone.
Source: Modified from Food and Agriculture Organization (2015), *Agroecology to Reserve Soil Degradation and Achieve Food Security*. Rome: Food and Agriculture Organization. http://www.fao.org/3/a-i4803e.pdf (accessed 10 May 2018).

Over a given period, agricultural damage and losses due to disasters accumulate, impacting the agricultural economy and limiting growth and development in this sector. For instance, the Philippines has been one of the ASEAN countries hardest hit by natural disasters, particularly typhoons, floods, and droughts. Between 2006 and 2013, the Philippines was affected by 75 disasters, mostly floods and typhoons or tropical storms, causing $3.8 billion in losses, of which $477 million was economic losses to the agriculture sector. From 2001 to 2010, the country endured a total of 184 typhoons (18 typhoons per year, on average). Natural disasters not only affect people, but also negatively impact the economy and environment in the affected area (FAO, 2015; Israel and Briones, 2012).

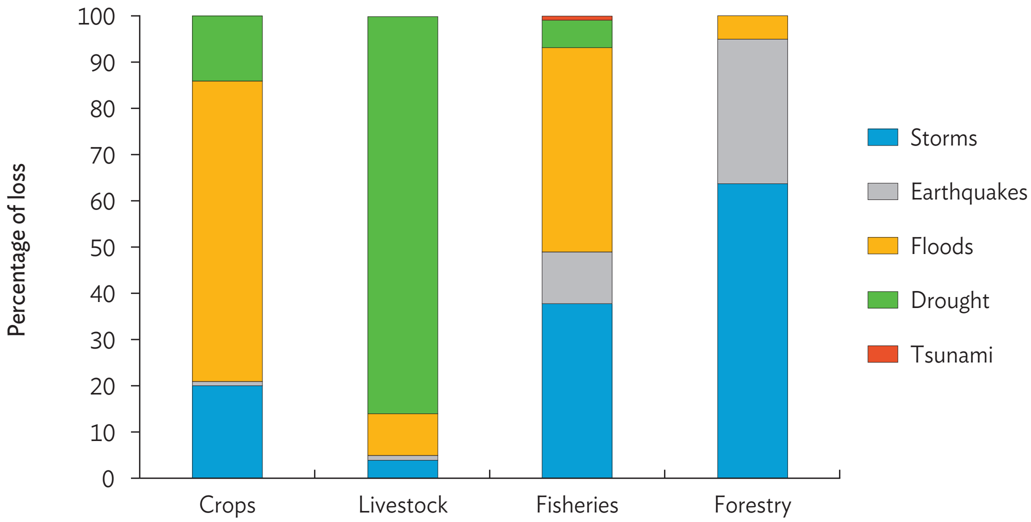
Globally, the average annual number of disasters between 2005 and 2014 (including all natural and climate-related disasters) was almost double the number of disasters that occurred in the 1980s. The occurrence of natural disasters, the damage that they inflict, and their impact on livelihoods and economies are increasingly having a major effect on Asia (Figure 1.3). According to the Emergency Events Database, in 2018, 301 country-level disasters occurred affecting 102 countries. In total, 6,261 natural disaster events occurred from 1997 through March 2018 affecting 4,419 million people; the damage inflicted resulted in around $267 billion in economic losses (Figure 1.3). Globally, disasters cause $250 billion–$300 billion in economic losses every year, on average. In developing countries during 2005–2016, there were, on average, 260 natural disasters every year, causing 54,000 fatalities, affecting more than 97 million people, and costing about $27 billion in economic losses (Emergency Events Database). From 2005 to 2014, natural disasters in developing countries caused approximately $93 billion in crop and livestock losses. In a study of 332 disasters in 87 developing countries from 2006 to 2016, the FAO found that agriculture—including crops, livestock, fisheries, aquaculture, and forestry—absorbed 23% of damages and losses from natural disasters. This rose to 26% in the case of climate-related disasters such as floods, droughts, and storms, indicating the susceptibility of smallholder farmers to natural disasters (Figure 1.4). Of the various kinds of disasters, floods are especially destructive, accounting for two-thirds of crop losses and related damage. In terms of crop losses, the 2010 flood in Pakistan is considered the most catastrophic recent disaster, causing almost $4.5 billion in damages. Another major recent disaster was the 2008–2011 drought in Kenya, which caused $1.5 billion in crop losses. In terms of livestock, the drought was the most harmful disaster, damaging 86% of the sector in Kenya, and causing $8.9 billion in losses. Floods and storms cause major losses for fisheries and aquaculture, while storms account for two-thirds of all disaster impacts on forestry, especially considering the impacts of the 2007 Hurricane Felix in Nicaragua and 2008 Cyclone Nargis in Myanmar (FAO, 2018).

Figure 1.3: The Impact of Disasters from 1997 to March 2018 on Different Continents



Source: Data from the Emergency Events Database, 2018 database. https://www.emdat.be/ (accessed 16 March 2019).

Figure 1.4: Percentages of Crop, Livestock, Fishery, and Forestry Losses Due to Storms, Earthquakes, Floods, Droughts, and Tsunamis (2006–2016)

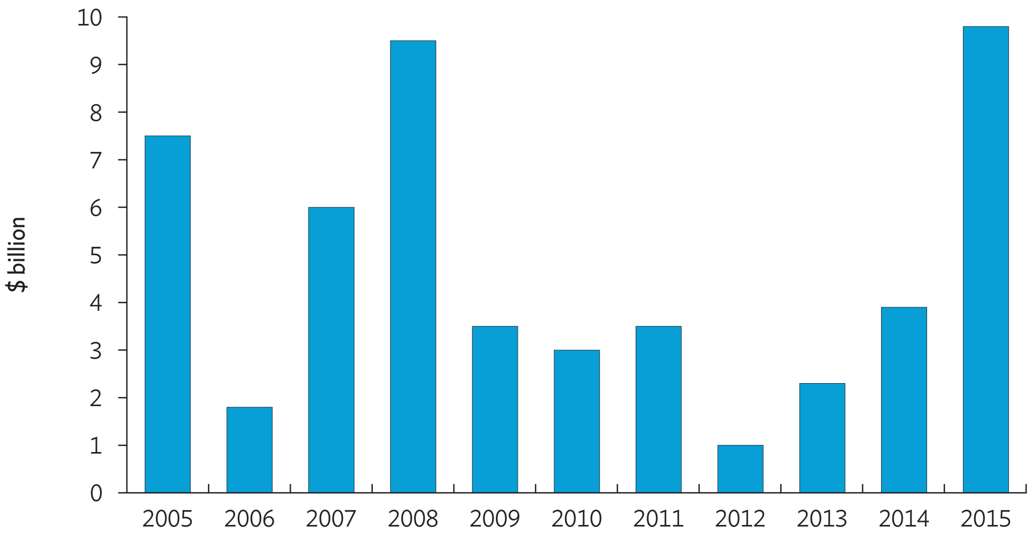


Source: Data from Food and Agriculture Organization (2017), *The Impact of Disasters and Crises on Agriculture and Food Security*. Rome: Food and Agriculture Organization. http://www.fao.org/3/I8656EN/i8656en.pdf (accessed 10 May 2018).

In Asia, agricultural production losses from 2005 to 2015 were found to be highest in the years 2008 and 2015 (Figure 1.5). The losses in these two years were primarily due to the sequence of monsoon floods and earthquakes that occurred in Southeast Asia. Asia's production loss in 2005–2015 was $48.0 billion (about 50% of total losses), of which $32.0 billion was lost in South Asia and $14.5 billion in Southeast Asia (FAO, 2017).

Some 70% of the world's disasters take place in developing, low-income countries (Gaire et al., 2016). Asia is the most disaster-prone area in the world, and is facing an increasing risk of natural disasters and resultant production losses. In particular, the presence of the Himalayas raises the probability of an outbreak of disasters, especially floods and severe droughts, in Asia in the coming decades (Kim et al., 2015). In addition to floods, Asian agriculture is challenged by earthquakes and tsunamis, which have caused losses of $9 billion so far, and by extreme temperatures, which account for over $7 billion in losses. These production losses correspond to 333 million tonnes of cereals, pulses, meat, milk, and other commodities. These losses are significant at the national level and highly significant at

Figure 1.5: Total Crop and Livestock Production Losses Due to Natural Disasters in Developing Countries in Asia (2005–2015)



Source: Data from Food and Agriculture Organization (2017), *The Impact of Disasters and Crises on Agriculture and Food Security*. Rome: Food and Agriculture Organization. http://www.fao.org/3/I8656EN/i8656en.pdf (accessed 10 May 2018).

the regional level (FAO, 2015). In Asia, disaster-related production losses were high across all commodity groups. Cereal production (especially of rice and wheat) registered $12 billion in losses over the past decade. Natural disasters also caused production losses of $7.3 billion in fruit and nuts, $6.0 billion in livestock, and $5.0 billion in vegetables (FAO, 2015).

The Global Climate Risk Index (CRI) developed by Germanwatch analyses quantified impacts of extreme weather events in different countries, considering fatalities as well as economic losses. The CRI determines the degree of exposure and susceptibility to extreme events by studying the deaths and economic losses caused by disasters. The CRI analyses the socioeconomic impact of extreme weather events such as floods, storms, landslides, earthquakes, droughts, wildfires, hail, and tornados. According to the 2018 CRI, which was created based on 20 years of data (1997–2016), the top 10 countries facing long-term climate risks include six Asian countries. Based on the average data for 20 years, the three most vulnerable countries in the world are Honduras, Haiti, and Myanmar. In general, developing countries are more susceptible to climate risk (Eckstein et al., 2018) (Table 1.1).

Table 1.1: The Long-Term Climate Risk Index of the 10 Countries Most Affected from 1997 to 2016 (Annual Averages)

CRI Ranking (1997–2016)	Country	CRI score	Total Losses ($ million) (PPP)	Losses per Unit GDP in %	Number of Events (1997–2016)
1	Honduras	12.17	561.11	1.968	62
2	Haiti	13.50	418.77	2.730	72
3	Myanmar	14.00	1,277.86	0.694	43
4	Nicaragua	19.33	234.60	1.127	44
5	Philippines	20.17	2,893.41	0.611	289
6	Bangladesh	26.50	2,311.07	0.678	187
7	Pakistan	30.50	3,816.82	0.605	141
8	Viet Nam	31.83	2,029.80	0.549	216
9	Thailand	33.83	7,696.59	0.967	137
10	Dominican Republic	34.00	243.53	0.262	49

CRI = climate risk index, GDP = gross domestic product, PPP = purchasing power parity.

Source: D. Eckstein, V. Künzel, and L. Schäfer (2018), 'Global Climate Risk Index 2018', *Bonn, Germany: Germanwatch*. https://germanwatch.org/en/14638 (accessed 10 May 2018).

Natural disasters are a major cause of food insecurity in the developing world, as they impact all four pillars of food security. They negatively influence economic and physical access to food supplies by affecting agro-ecosystems via decreased crop production, loss of fisheries, and livestock reduction. Natural disasters also make it difficult to control weeds, pests, and the spread of diseases (Figure 1.2). Disasters such as droughts and floods also have long-term impacts and can abruptly influence victims' earning capacity, causing standard asset losses for people who depend on agriculture, and subsequently affecting food prices and the food supply chain. It is estimated that the food price index doubled from 2002 to 2011 due to recurrent increases in agricultural commodity prices. This increase was associated with three drought incidents (2001–2007) in Australia and a heat wave during the summer of 2010 in Central Asia, amongst other disasters (FAO, 2015).

Agriculture is considered one of the main economic activities in developing countries accounting for 10%–20%, on average, of the national gross domestic product (GDP) in middle-income countries, and more than 30% of GDP in low-income countries. In countries where the economy is driven by agriculture, disasters can trigger major losses, up to 30%–40% of both national GDP and employment. For example, damage to fisheries caused by the

2016 tropical cyclone in Fiji reached about $100 million, or 2.3% of the country's 2015 GDP. Similarly, GDP growth in Indonesia has been limited by recurrent wildfires that have cost the country an estimated Rp221 trillion, more than twice the renovation cost of the 2004 tsunami (World Bank, 2016). In Nepal, agriculture (including a mix of crop and livestock production) accounts for 34% of annual GDP. In 2015, in earthquake- and landslide-struck basins, and in other parts of central Nepal, more than 73.3% of the population depends on agriculture, either for survival or for commercial farming (Government of Nepal, 2015). Similarly, in a study of average 5-year growth during 1961–2005, disasters were observed to have a significant impact on GDP, with droughts having a negative effect, and floods having a positive effect (Israel and Briones, 2012). The effects of natural disasters differ based on the type and severity of the disaster (Fomby, Ikeda, and Loayza, 2013). For example, during 1991–2013, drought had detrimental effects on crop and livestock in sub-Saharan Africa, causing production losses of 90%, or more than $30 billion (FAO, 2015). However, in a few cases floods had positive effects due to the greater availability of water, which benefitted the crops and provided additional nutrients carried from the uplands to lowlands (Israel and Briones, 2012). Floods also temporarily create a more abundant water habitat for inland fish and other aquatic animals. However, when flooding is severe, this positive effect can vanish and it can damage farm infrastructure, supplies, facilities, and stored seeds (Loayza et al., 2012). The frequency of extreme weather has been rising globally, indicating the urgent need for Asia to adapt to natural disasters. Understanding the damage and loss sustained by the agricultural sector is key for managing disaster risks and supporting national resilience policies, planning, and action.

1.3 Effects of Climate Change on Food Security

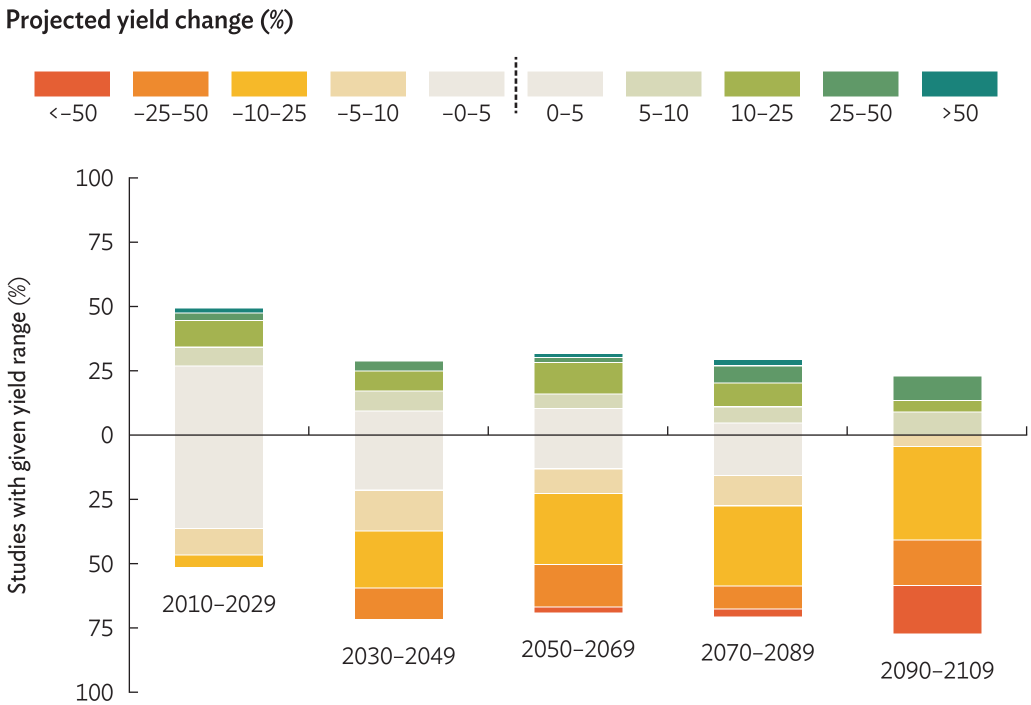
The Intergovernmental Panel on Climate Change (IPCC) defines climate change as 'a change in [the] state of the climate that can be recognised (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer' (IPCC, 2012). Changes in the climate occur due to natural processes and external factors caused by human activities, such as burning fossils emitting greenhouse gases, farming, and deforestation; these changes impact natural resources, biodiversity, land use, and agro-ecosystems, amongst other things. The main characteristics of climate change are an increase in average global temperatures, changes in precipitation patterns, the melting of glaciers and polar ice caps, an increase in ocean temperatures, and increased ocean acidity due to seawater absorbing heat and carbon dioxide (CO_2) from the atmosphere. These changes are expected to continue and intensify in the future

(Solomon et al., 2007). Global climate change has already had observable effects on the environment. It has also been predicted that climate change over the next century will modify river flows and sea levels throughout the globe, and affect rainfall (IPCC, 2008).

Research has shown that agricultural yields will likely be severely affected over the next century by unusual rates of change in the climate system (Jarvis et al., 2010; Thornton et al., 2011). Climate change greatly influences the conditions in which agricultural activities are conducted. Plants, animals, and ecosystems in every region of the world are adapted to the prevailing climatic conditions. For instance, in experiments conducted in controlled conditions, some cultivated C_3 plants react favourably to an increase in atmospheric CO_2 by producing more biomass and increasing the yield. Similarly, many weeds that compete with crop plants for nutrients and water also reacted favourably to increased levels of CO_2. Studies show that elevated CO_2 levels selectively favour invasive and noxious species of weeds, stimulating their growth and making them difficult to control (Ziska and George, 2004). A rise in CO_2 concentrations changes the strength of plant defences against pests and pathogens (Zvereva and Kozlov, 2006), permitting pests and weeds to establish themselves (Rosenzweig et al., 2001). Pests and diseases are also influenced by changes in the climate, with possibly negative impacts. Climate change will also impact the abundance and distribution of pollinating insects, which may reduce the pollination of flowering plants, lowering their production (Hegland et al., 2009). Hence, climate change alters the relationships that exist amongst crops, pests, pathogens, and weeds. Climate change reduces crop yields by affecting pollinating insects, creating water scarcity, increasing ground-level ozone concentrations, and reducing fishery production (Myers et al., 2017) (Figure 1.3).

Although some crops can see yield increases when CO_2 levels are elevated, the higher temperatures caused by increased CO_2 reduce crop yield. Crop growth models that study the effects of CO_2 combined with the effects of temperature, water availability, and limited nitrogen have predicted yield losses (Figure 1.6) (Challinor et al., 2014; Rosenzweig et al., 2014). Changes in production caused by climate change will surely impact food commodity prices, making them difficult to buy in vulnerable countries. According to modelling studies that compare scenarios ‘with’ and ‘without’ climate change, estimated world market export prices in 2030 relative to 2010 export prices will rise by a higher percentage in the ‘with’ climate change scenario than in the ‘without’ climate change scenario (Willenbockel, 2011). Global sea-level rise from glaciers melting due to thermal expansion will affect food security by flooding agricultural lands near coastal areas and increasing the salinisation of groundwater (Adams, 1989; Myers et al., 2017). Additionally, rising sea levels also cause destructive

Figure 1.6: Estimated Output Reduction in Crop Yields Due to Climate Change (2010–2109) (%)



Source: Challinor, A. J., J. Watson, D. B. Lobell, S. M. Howden, D. R. Smith, and N. Chhetri (2014), 'A Meta-Analysis of Crop Yield Under Climate Change and Adaptation', *Nature Climate Change*, 4(4), p. 287.

erosion, wetland flooding, soil contamination, and habitat loss for fish. Salinity levels in the soil can significantly influence plant growth and production, as well as the quality of available drinking water (Adams, 1989; Myers et al., 2017; Shrivastava and Kumar, 2015).

Asia is particularly vulnerable to climate change because it has high population densities in vulnerable areas exposed to climate-related hazards such as floods, cyclones, and droughts, as well as long-term climate changes such as gradual changes in monsoon patterns, glacier melt, and sea-level rise. In Asia, most vulnerable people live in the river deltas of Bangladesh, Cambodia, India, Myanmar, Viet Nam, Thailand, and Pakistan, where rising sea-levels will affect 2 million people by 2050, and result in the loss of farming areas in coastal regions (Table 1.2) (Webster, 2008). The IPCC (2014) estimates that, by 2050, rising sea levels could directly displace more than 3 million people living in delta areas in

Table 1.2: Loss of Agricultural Area from Sea-Level Rise in ASEAN Countries (hectares)

	With a 1-meter rise	With a 3-meter rise
Myanmar	295,000	1,214,000
Thailand	199,000	796,000
Cambodia	35,000	118,000
Viet Nam	2,513,000	4,281,000

ASEAN = Association of Southeast Asian Nations.

Source: Asian Development Bank (2012). *Guidelines for Climate Proofing Investment in Agriculture, Rural Development, and Food Security*. Manila: Asian Development Bank. https://www.adb.org/sites/default/files/institutional-document/33720/files/guidelines-climate-proofing-investment.pdf (accessed 4 May 2018).

Bangladesh and 7 million–18 million in Viet Nam. Sea-level rise will also cause losses of arable land in Asia, which produces 88% of the world's rice. According to the FAO, more than 100 million hectares of agricultural land in Bangladesh and 2.6 million hectares of land in Viet Nam, where rice is the predominant crop, will be affected by the 1-meter rise in sea levels. As most of the population in these countries depends on farming and fishing, the rise in sea levels will impact their livelihoods. Increased temperatures are also expected to cause the glaciers in the Himalayan region to melt, causing more frequent flooding in the short term and higher risk of drought in the long term. Wheat production along the Indus Valley depends on water from these glaciers, and the risk of flooding and drought can stress sensitive livelihoods in these regions. Sea levels are expected to rise by an estimated 57–100 centimetres by the end of the century, exacerbating coastal flood risks and storm surges and impacting livelihoods in coastal areas. Each year, the Philippines is threatened by about 19 tropical cyclones, of which between six and nine make landfall, with devastating effects on crop production, land, agricultural tools, and fishing boats. Climate projection studies show that large parts of Southeast Asia will experience changing rainfall patterns due to substantial changes in the climate, which will impact rain-fed agricultural systems (FAO, 2017).

Quantification studies of 23 Southeast Asian cities indicate that rising sea levels will expose an estimated $864 billion in assets to floods by 2100. Losses will also be inflicted on infrastructure, industries, coastal zones, and agriculture in the region. In the next century, it is estimated that Indonesia, the Philippines, Thailand, and Viet Nam will face mean economic losses from climate-induced disasters equal to losing 6.7% of their collective GDP each year, double the global average loss (Asian Development Bank [ADB], 2014).

One of the most significant impacts of climate change is the potential increase in food insecurity due to changes in the productivity of agricultural land, seasonal variability, and greater magnitude of disasters. Climate change affects all four dimensions of food security in complex ways. Variations in crop yields influence food availability, especially in key producing areas, due to rising temperatures, a decrease in or loss of arable land, and low availability of water for agriculture. Production losses can strain the capacity of households to access food and can influence dietary diversity. Additionally, changes in rainfall and temperature patterns directly impact livelihoods that depend on climate-sensitive activities, such as rain-fed agriculture and livestock rearing. Low water availability may cause sanitation problems and affect the quality of available drinking water, causing health concerns. Combined with other vector-borne infections, there is a possibility of increased malnutrition influencing food utilisation. Climate-related extreme weather events also disturb the stability of the food supply and of livelihoods. According to the IPCC (2008), the degree of climate change impacts on individual regions will vary over time and with the ability of different societal and environmental systems to adapt to change.

1.4 Adaptation Strategies

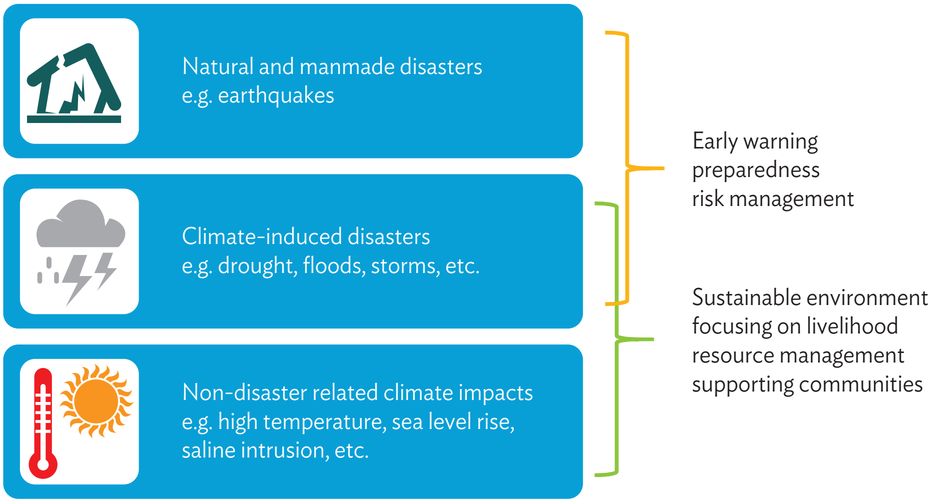
Natural disasters must be understood from a disaster risk framework. To assess the disaster risks faced by economies across Asia, each economy has been examined in the light of disaster indicators such as the frequency of intense hydrological disasters, the number of people affected by these catastrophes, the number of people killed by these events, and the corresponding indicators of meteorological disasters. The UNISDR (2009) defines disaster risk management as 'the systematic process of using administrative directives, organisational and operational skills and capacities to implement strategies, policies and improved coping capacities to lessen the adverse impacts of hazards and the possibility of disaster.' In most cases of natural disasters, prevention is not entirely sufficient, and the risk cannot be reduced to zero (World Bank, 2016). Hence, it is vital to implement decisive risk management strategies to mitigate natural disasters where risk cannot be avoided.

To date, much consideration of adaptation management has focussed on climate change initiating gradual and long-term changes on average climate conditions. However, risks from changes like extreme events and climate variability (e.g. droughts, floods, storms, coastal erosion, and earthquakes) are the most significant, requiring immediate attention. Climate change will intensify existing problems resulting from the increase in water demand, temperatures, number of extreme events, and climate variability over the next few decades.

Every year, natural disasters and climate-related extreme events result in substantial loss of life, economic damage, and social development (IPCC, 2008).

Adaptation is a major factor that will shape the future severity of climate change impacts on food production (Chang, 2007). Adaptation to climate change and disaster risk management both seek to reduce negative factors and modify environmental and human contexts that contribute to climate-related risk, thus supporting and promoting sustainability in social and economic development (IPCC, 2012). Both disaster risk reduction and climate change adaptation practices involve learning to deal with existing and projected future risk. Overlaps between these two types of practices occur when there are common concerns such as droughts, extreme heat events, floods, and storms (Figure 1.7).

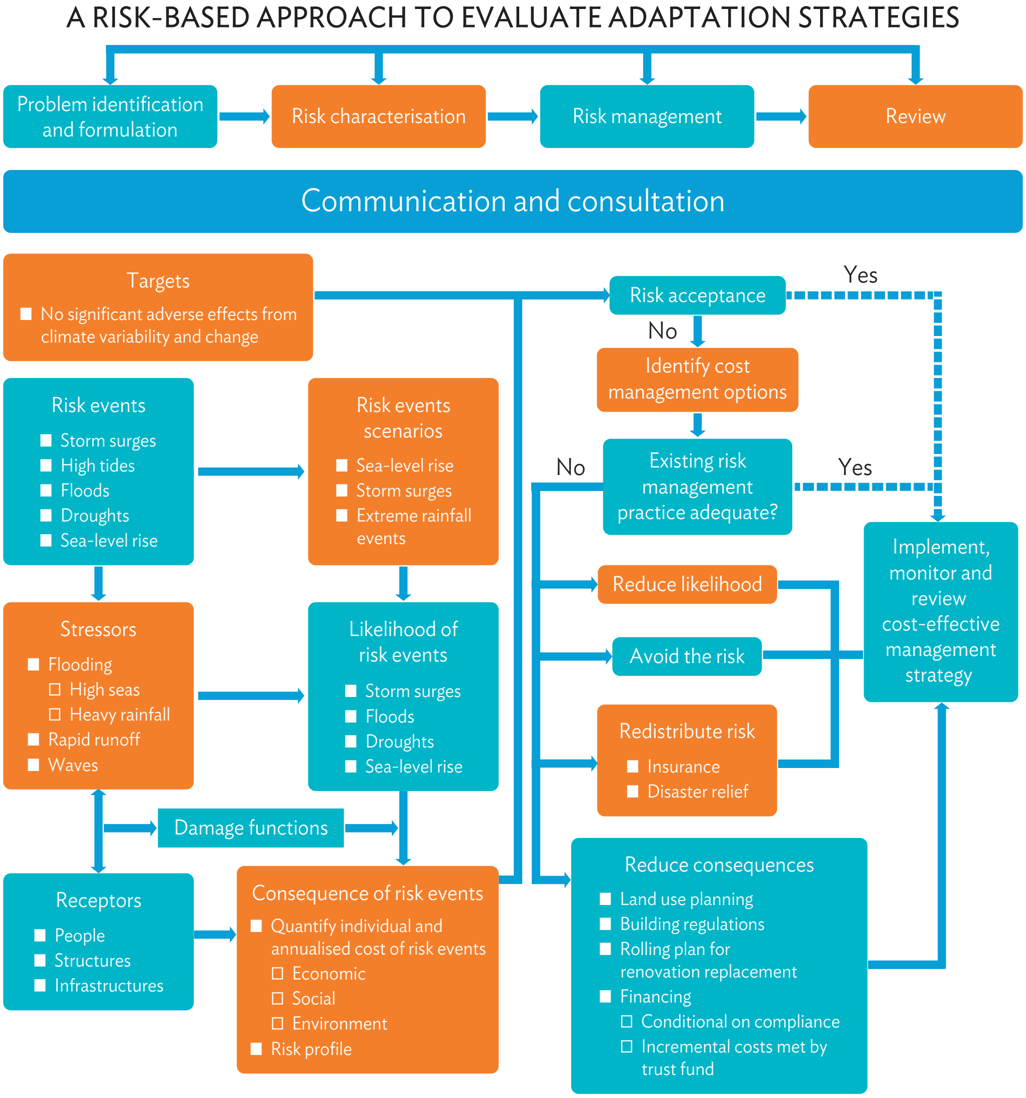
Figure 1.7: Climate Change Adaptation and Disaster Risk Reduction Adaptation Integration



Source: Authors.

In practice, adaptation strategies should concentrate on reducing both present and future risks related to natural disasters and climate-related extreme events. However, most current international climate change agreements and associated funding focus primarily on reducing future risks. To achieve better adaptation to address present risks and face future risks, it is necessary to (i) understand the drivers of and barriers to adaptation strategies; (ii) identify and assess adaptation options for both existing and future risks; and (iii) implement, evaluate, and monitor adaptation approaches. There are several frameworks and strategies for an integrated approach to disaster risk reduction and climate change adaptation. We discuss some of these strategies below.

Figure 1.8: Risk-Based Approach – Planned Risk Characterisation and Management Procedures



Source: Climate Change Adaptation Through Integrated Risk Reduction findings in Asian Development Bank (2005), *Climate Proofing: A Risk Based Approach to Adaptation*. Manila: Asian Development Bank. https://www.adb.org/publications/climate-proofing-risk-based-approach-adaptation (accessed 4 May 2018).

Figure 1.9: Adaptation Strategies for Disaster Risk Reduction and Climate Change

Vulnerability	Risk management	Implement food production system	Conservation of natural ecosystem	Strengthening local institutions
Identify the vulnerable groups and determine vulnerability	Risk awareness: making databases available to raise awareness of disasters and climate change	Implement food production system to balance the supply and demand for food security	Sustainable agriculture: soil conservation, environmentally friendly technologies, and farming practices to increase soil carbon	Enhance information and communication capacity among locals, and farmer to farmer knowledge transfer (indigenous knowledge)
Formulate policies to help communities to adapt	Risk preparedness: early warning and training	Agricultural technologies: resource use efficiency (water, nutrients, and pesticides)	Communal gardens, backyard gardens, and crop residue management	Improve scientific capacity and organise regional adaptation programs
Associate policy-related actions to reduce adverse effects	Risk transfer and prevention: insurance, policy planning, and implementation	Farmers support: increase support to farmers, improve their ability, and develop farmer institutions	Diversification, promoting organic agriculture, and sustainable fishery farming	Collective action and gender equality

Source: Authors.

1.4.1 | Adaptation Approaches

Adaptation has many dimensions, as it is a constant and flexible process that limits or decreases exposure to risk from natural disasters, climate change, and related extreme weather events. Risks associated with current levels of climate change and disasters typically cause severe losses to societies, economies, and the environment. Current adaptation strategies are frequently insufficient to deal with the high costs of disasters and changes in the climate. Adaptive capacity comprises two measurements: recovery from shocks, and response to changes in the climate. Resilience to risk can be achieved by reducing risk exposure and sensitivity, and enhancing adaptive capacity. Actions can be implemented across biophysical, economic, or social domains. The most suitable forms of adaptation are usually those that build on current efforts to cope with existing climate variability and extreme events, while contributing positively to sustainable economic development, environmental management, social progress, and resource use in the future.

Decision makers have various options (e.g. low- or no-regret, win-win, whole-system, top-down, and bottom-up) in planning adaptation to climate change and risk management. The most suitable choice will be determined based on the nature of the decision being made, level of risk, and understanding of the specific climate impacts. Climate risk management approaches adopted by national governments and development agencies (e.g. the United Nations Developmental Programme, United Nations Office for Disaster Risk Reduction, FAO, World Bank, ADB, and Global Facility for Disaster Reduction and Recovery) usually encourage sustainable development by reducing vulnerability to climate risks and thereby achieving resilience. Climate risk management using a 'no regrets' approach includes proactive plans to maximise positive outcomes and reduce negative effects for societies and economies in climate-affected sectors such as agriculture, food security, water resources, and health (United Nations Development Programme, 2010). Under this approach, decision makers take actions that have long-term benefits, even in the absence of climate change, by building resilience to changing economic, social, and environmental conditions. For example, in Nicaragua, researchers have managed to calculate a 'narrow niche' where it is still viable to grow Arabica coffee, but recommend switching to a different crop as temperatures increase. At lower altitudes, they suggest growing cocoa as it has the same cash value as coffee and is suited to the new growing environment. Although high altitudes are suitable for coffee farming due to the availability of water and other resources, controlling the expansion of coffee farming is recommended. The researchers also suggested ensuring that any high-elevation expansion of the crop can be achieved without harming the environment. Farmers are advised to adjust their agricultural practices based on the altitude as the climate changes, by adapting shade-grown varieties (Vermeulen et al., 2013).

In terms of climate-related extreme weather events, climate risks are very high because the risk has been intensifying over the past few decades. A risk-based climate-proofing approach to adaptation is not only desirable but also feasible. It is essential to identify the risks associated with disasters and climate change, and manage them to reduce their impacts. The risk-based approach uses the probability of climate-related effects and looks at the consequences of both existing and future conditions. This approach offers an opportunity to study a specific event only, or a combination of several events over time. The risk assessment and management approach can also be applied to other sectors besides the food sector, such as the health, financial, transport, energy, and water resources sectors. Current knowledge of disaster risk management will help decision makers and planners establish and implement the risk-based management options. Since the adaptation process usually involves many players, the framework of the risk-based approach enables coordination and cooperation, such as information sharing, amongst these various players (ADB, 2005). Based on the risk-based approach, six case studies were planned to help ADB's Pacific developing member countries adapt to existing and future climate risks by using the Climate Change Adaptation Through Integrated Risk Reduction framework and methodology shown in Figure 1.8. This approach, which proved to be very useful, can be applied at three levels: project activities, national development planning and sector programmes, and country strategies and programmes. Under the climate-proofing approach, most of the damage caused by climate change to infrastructure projects can be avoided if the right strategies are implemented at the project design stage (ADB, 2005).

1.4.2 | Principles of Successful Adaptation

The principles of successful adaptation for decision making should have the following qualities:

(i) Adaptation should be **holistic** to manage and reduce risks associated with disasters and climate change. This highlights the need to establish both disaster risk management and adaptation to climate variability and extreme events by making them integral components of national risk management strategies.

(ii) Adaptation should be **efficient** to address long-term impacts while reducing short-term effects. The benefits should also be long-term and cover all costs, making them essentially cost-efficient.

(iii) Adaptation should be **evidence-based** considering the data from the scientific community and research organisations. Adaptation largely depends on generating an information or evidence base, and an understanding of how a given system functions to inform the development of effective adaptation strategies. Awareness of the issues involved in adaptation helps in the process of risk identification. Thus, it is necessary to establish an evidence base upon which the level of risks can be analysed and evaluated to determine their significance and to avoid maladaptation.

(iv) Adaptation measures must be **monitored and reviewed** during implementation, which may require new monitoring and reporting systems.

(v) Adaptation management should consider the physical and biological features of an area, as well as the institutions and people who influence it. The interconnection of these factors helps decision makers work in an **integrated** way across sectors to address environmental, social, and economic issues.

(vi) Adaptation actions should be **flexible**. Since there is ambiguity regarding the future state of the climate, options should include decisions that maximise future flexibility.
(vii) Adaptation measures should be **effective** to reduce the risks of disasters and climate change without any adverse effects on the environment, society, and economy.
(viii) Actions should be **prioritised** based on the impacts of disasters and climate variability by focusing on areas where people are most vulnerable, the economy is at stake, and critical national infrastructure is involved.
(ix) Actions should be **environment-friendly** based on the ecosystem to enhance the capacity of natural systems and resist future climate-related extreme events.

Adaptation strategies for disaster risk reduction and climate change should be established based on the assessment and prioritisation of risks that people face as well as their ability to adapt. These strategies include early warning systems, monitoring, and evaluation for enhanced coping and adaptation (Department for International Development, 2011). The adverse effects of natural disasters and climate variability can significantly affect all four dimensions of food security. The specific implications for food security depend on whether a disaster affects food availability, physical and/or economic access to food, or both. During disasters, the extent of any shortfall in food availability depends on local food availability, access to regional food reserves, and food assistance from national and international organisations. However, when disasters damage transportation systems, people living in the affected areas usually face significant shortfalls in food availability. The principal objective of risk management should be to reduce the impact of natural disaster risks and build resilience to food insecurity by making food available to affected people. For example, the ASEAN Plus Three Emergency Rice Reserve (APTERR) was established in 2011 as a buffer against immediate threats to food security caused by disasters and market vitality associated with climate calamities. The objectives of the APTERR are to make rice available during emergencies, stabilise the price of rice, and improve farmers' income and welfare. The scheme aims to improve food security without distorting the international rice market. APTERR stocks can be released to a member state that is unable to cope with an emergency using its natural reserves alone and is unable to procure the needed supplies through regular trade (Trethewie, 2013).

Significant adaptation strategies comprise such essential elements as early warning systems, farm-level management to optimise production, related technologies, capacity building, and awareness raising to understand and undertake adaptation. We discuss some of the aspects of adaptation below (see Figure 1.9).

1.4.2.1 Vulnerability

Adaptation measures require widespread information on agricultural, environmental, economic, and social systems affected by disasters and extreme climate events, with the aim of carrying out accurate vulnerability assessments. Vulnerability assessments help decision makers understand the impacts of changes in the climate and seasonal variability on agricultural systems, and formulate policies to help communities adapt. However, agricultural production systems have their own dynamics, and adaptation especially emphasises future agriculture. The future vulnerability of the community or country depends not only on climate change but also on the type of development pathways that are adopted.

1.4.2.2 Risk Management

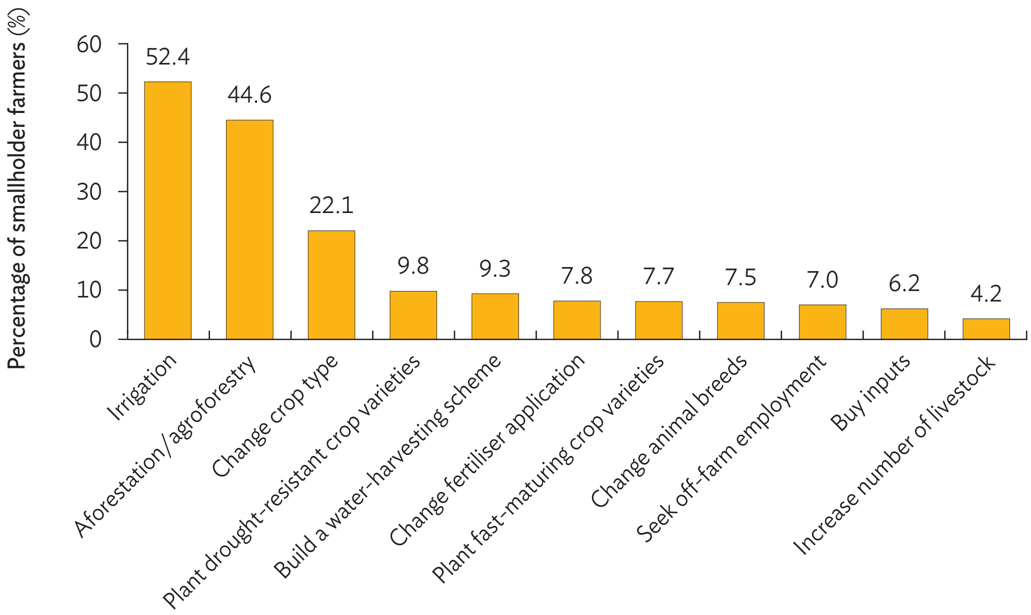
Early warning systems are very effective contributors to adaptation and risk management (FAO, 2017). Management of disaster risks depends on the source, monitoring, and dissemination of information (Eiser et al., 2012). In addition to monitoring the weather, it is essential to monitor food reserves in the case of emergencies and prepare for a disaster situation. Developing the components of an early warning system as well as the correct type of information and communications technology assists in evaluating a given situation and planning accordingly. In most situations, people adapt to climate change by modifying their behaviour according to the change or migrating to another location. An early warning system and the development of other useful technologies will make it possible for people to adapt to expected changes. Farmers can utilise hard technologies (e.g. irrigation systems and tolerant crop varieties and livestock breeds), soft technologies (e.g. insurance schemes and crop rotation patterns), or both (UNFCC, 2006). Technological improvements also help researchers disseminate information and data to the public and farmers more quickly (Toya and Skidmore, 2015). The information helps farmers make decisions about cropping schedules, variety selection, nutrient use, diseases, and water use schedules. The information is made available to farmers in developing countries through satellites, websites, mobile phones and applications, and hotline services, with the aim of reaching, warning, and preparing the farmers for extreme weather events (Kaur et al., 2015).

In addition to risk awareness and preparedness, risk transfer and sharing is another way of managing risk by distributing losses caused by extreme weather events and climate variability (Linnerooth-Bayer and Hochrainer-Stigler, 2015). Financial tools decrease the burden of loss on farmers and other affected people, as the reduction of losses by natural disasters and climate change can be expensive (Linnerooth-Bayer and Hochrainer-Stigler, 2015). Financial instruments for farmers include pre-disaster savings, post-disaster credit, and insurance, which for the poor can take the form of stockpiles of food, grains, seeds, and/or exchangeable assets that are useful in medium-risk cases. Microsaving or saving before disasters protected the economy of women's empowerment in the Philippines, including decision-making power over purchases and children's education (Ashraf et al., 2010). Microfinancing is another financial tool that can protect farmers from potential losses in crop, livestock, and fishery production due to disasters (Johnston and Morduch, 2007). Farmers receive automated insurance payouts in the event of disaster loss, encouraging them to not sell their assets (Reddy and Anbumozhi, 2017).

1.4.2.3 Implementing Food Production Systems

Farm practices such as optimising production, farming technologies, and diversification can be used to fill production gaps. Farm-level adaptation options used by farmers to improve production are presented in Table 1.3. Several knowledge-intensive forms of agriculture are available, and the necessary technology and encouragement should be offered to encourage farmers to accept and adopt them (Nelson et al., 2009). According to the FAO (2018), climate-smart agriculture involves a combination of agronomic practices for soil and water management, improved infrastructure and equipment for disaster risk management, and research and development for adapted crop seeds and technologies. These are some of the strategies recommended to optimise agricultural production and food security. Among the adaptive measures adopted by farmers in response to climate change, some of the most common are agroforestry practices, crop diversification, early planting, increased use of early maturing varieties and stress-tolerant crop varieties, wild plant gathering, and mixed cropping production systems (Altieri and Koohafkan, 2008; Verchot et al., 2007; Silvestri et al., 2012). The farmers prefer some strategies, such as irrigation, agroforestry, and crop diversification, over the others (Figure 1.10) (Silvestri et al., 2012). Agricultural diversification, including the addition of new crop varieties and livestock breeds, mixed cropping, crop rotation, and inter-cropping, is considered the best strategy for optimising production (Reddy and Anbumozhi, 2017). Diversification has very positive effects, such as reducing the effects of adverse weather conditions such as droughts and erosion, slowing the spread of pests and diseases, reducing input, and increasing yield (Fadina and Barjolle, 2018). National and international agricultural research organisations have made several varieties tolerant of drought, heat, and salinity available to farmers. Diversification improves soil fertility, boosts protein consumption, and diversifies diets (Headey and Kennedy, 2012). With regard to livestock, trying to raise new strains of livestock will help make agricultural systems more resilient.

Figure 1.10: Desired Adaptation Strategies by Smallholder Farmers



Source: Silvestri, S., E. Bryan, C. Ringler, M. Herrero, and B. Okoba (2012), 'Climate Change Perception and Adaptation of Agro-Pastoral Communities in Kenya', *Regional Environmental Change*, 12(4), pp. 791–802.

Farm practice technologies, such as new irrigation techniques to handle drier climates, are suggested to manage water resources, maximise resource use, and improve production. For example, the drip-irrigation method utilises water efficiently by supplying water frequently and in small quantities to the root zone through plastic pipes. Micro-irrigation, or low-pressure pipes equipped with water filters and smart metered solar utility models for localised areas in sub-Saharan Africa ensured the delivery of water and nutrients directly to the root zone and facilitated the efficient use of resources (Burney and Naylor, 2012). Establishing farmer institutes encourages farmers to interact with each other and share farming knowledge. Building household storage facilities such as small storage facilities, moisture-proof containers, and plastic bags is also necessary to cope with seed shortages in the event of disasters. For example, monsoon rains in Nepal (Dey, 2015) and Haiti (McGuire and Sperling, 2013) and floods in Pakistan (Doocy et al., 2013) destroyed farmers' seeds. Distributing cheap, low-oxygen grain storage bags in the event of disasters will help farmers temporarily store and save seed (Chapagain and Raizada, 2017).

Table 1.3: Options for Adaptation to Climate Change at the Farm Level

Risk	Response
Changing climate and climate variability and seasonality	• Participate in monitoring schemes when available. • Optimise planting schedules such as sowing dates (including for feedstocks and forage). • Plant different varieties, species, or cultivars of crops. • Use short-duration cultivars. • Varieties or breeds with different environmental optima, or those with broader environmental tolerances, may be required. The use of currently neglected or rare crops and breeds should be considered. • Early sowing enabled by improvements in sowing machinery or dry-sowing techniques • Increased diversification of varieties or crops to hedge against risk of individual crop failure • Use intercropping. • Make use of integrated systems involving livestock and/or aquaculture to improve resilience. • Change post-harvest practices, for example, the extent to which grain may require drying and how products are stored after harvest. • Consider the effect of new weather patterns on the health and wellbeing of agricultural workers.
Change in rainfall and water availability	• Participate in monitoring schemes when available. • Change irrigation practices. • Adopt enhanced water-conservation measures. • Use marginal and wastewater resources. • Make more use of rainwater harvesting and capture. • In some areas, increased precipitation may allow irrigated or rain-fed agriculture in places where it was not previously possible. • Alter agronomic practices. • Reduce tillage to lessen water loss, incorporate manures and compost, and employ other land use techniques such as cover cropping to increase soil organic matter and hence improve water retention.
Increased frequencies of droughts, storms, floods, wildfire events, and sea-level rise	• Participate in monitoring schemes. • General water conservation measures are particularly valuable during times of drought. • Use flood-, drought-, and/or saline-resistant varieties. • Improve drainage, soil organic matter content, and farm design to avoid soil loss and gullying. • Consider increasing insurance cover against extreme events.
Pests, weeds, diseases, and the disruption of pollinator ecosystem services	• Participate in risk monitoring and preventing schemes when available. • Use expertise in coping with existing pests and diseases. • Build on natural regulation and strengthen ecosystem services.

Source: Food and Agriculture Organization (2017), *Benefits of Farm Level Disaster Risk Reduction Practices in Agriculture*. Rome: Food and Agriculture Organization. http://reliefweb.int/sites/reliefweb.int/files/resources/a-i7319e.pdf (accessed 10 May 2018).

1.4.2.4 Conservation of Natural Ecosystems

Ecosystem-based adaptation includes several management activities to improve the resilience and reduce the vulnerability of both people and the environment to disasters and climate change. Adaptation strategies for the conservation of natural ecosystems are soil and agriculture conservation, forest conservation (such as mangrove conservation), integrated pest management, livestock and fisheries management, and coral restoration (Keys and McConnell, 2005; Pretty and Bharucha, 2014). To conserve agriculture to meet future agriculture and food security demands, it is necessary to restore natural assets by improving farmland and ecosystem management (Reddy and Anbumozhi, 2017). This also minimises the scope for maladaptation in developed and developing countries. Other ecological restoration practices include agroforestry activities such as planting trees, climate-smart landscapes, communal gardens, intercropping, and livelihood diversification in disaster-prone areas. Ecosystem restoration and development also minimise greenhouse gas emissions. Thus, the species chosen to restore communal areas must be able to meet a variety of environmental, social, and economic needs (Kumar et al., 2015). A strategic plan to improve soil health and reverse soil degradation is required to increase food production and improve food security. Organic agriculture and sustainable fisheries are other options to conserve the natural ecosystem. Active ecological restoration requires institutional frameworks to ensure that all stakeholders have fair access to benefits from the natural resources on which their livelihoods depend (Kumar et al., 2015).

1.4.2.5 Strengthening Local Institutions

As local communities are the first to respond when a disaster happens, increasing the disaster management capacity of these communities and local governments is the most effective way to improve disaster management and climate change. Efforts to build capacity for food security involve enhancing the ability of individuals, groups, organisations, and communities to meet their food security challenges sustainably. In the long run, this cannot be achieved without qualified local individuals and institutions to provide direction and motivation to manage these efforts. This requires the development of teamwork amongst farmers, extension agents, scientists, and, frequently, different government ministries and nations (Alcayna et al., 2016).

Achieving adaptation at the global, national, and regional levels requires the strengthening of the governance system to coordinate adaptation measures. Prioritising initiatives through policy support such as technologies that strengthen the resilience of farming systems to disasters at the regional level can lead to sustainable agriculture. Establishing a relationship between policymakers, the scientific community, and professionals from all food-related sectors will help in the development of new decision-support systems to improve the capacity of farmers, fishers, and forest-dependent people to adapt their livelihoods to climate change and disasters (FAO, 2017). Another important aspect that should be investigated is the dimensions of climate change impacts and adaptation patterns on gender. Climate change influences men and women differently because of differences in their access to resources and climate adaptation practices. Women are crucial actors in maintaining and improving food security in the face of climate change. Thus, it is necessary to consider women's needs for improved access to education and the labour market, and greater participation in decision making (FAO, 2017).

1.5 Recommendations to Improve Medium- and Long-Term Resilience

1.5.1 | National Level

(i) Improve information systems to provide reliable weather forecasts to farmers and public databases to educate people on disaster risk reduction and climate change adaptation.
(ii) Improve rural roads and production infrastructure, and enhance access to markets.
(iii) Enhance farm productivity through agricultural research, extension services, and post-harvest measures.
(iv) Strengthen human capacity by working explicitly with community organisations and including the most vulnerable people, particularly women.
(v) Introduce insurance and disaster mitigation measures such as crop insurance, credits, and futures contracts.
(vi) Increase food stockpiles for use during poor production years, and establish regional food reserves as a crisis management system.

1.5.2 | Regional Level

(i) Promote research and development, knowledge exchange, and capacity building.
(ii) Improve the monitoring and surveillance of agricultural production and food market conditions.

(iii) Promote trade liberalisation.
(iv) Consider mechanisms to promote price stability, such as regional food reserves.
(v) Enhance collaboration on climate change under the ASEAN Sociocultural Blueprint.
(vi) Enhance collaboration on disaster risk reduction under the ASEAN Agreement on Disaster Management and Emergency Response.

1.6 Summary

Natural disasters and extreme weather events due to climate change can cause agricultural production losses affecting food security and its components, including availability, access, utilisation, and stability. Reduced food production due to disasters and climate change raises commodity prices, affecting the ability of the population in vulnerable societies to access food markets, and influencing livelihoods. Adaptation strategies to reduce vulnerability and increase resilience are required to achieve food security in the event of natural disasters and climate change. This chapter discussed principles for better adaptation and various integrated adaptive strategies to cope with and manage natural disasters, reduce risk, and adapt to climate change to ensure food security. Principles for effective adaptation should include approaches that are holistic, efficient, sustainable, prioritised, and effective. Adaptation approaches must incorporate plans that not only target existing climate conditions, but are flexible to react to future climate conditions and address the causes of vulnerability. The strategies discussed here are to (i) address vulnerability, (ii) manage risks, (iii) implement food production systems, (iv) conserve natural ecosystems, and (v) strengthen local institutions. Each section discussed different adaptation measures, including (i) upscaling modern technologies such as conservation and climate-smart agriculture, (ii) using water and nutrients for agriculture efficiently through micro-irrigation and water-saving technologies, (iii) diversifying crops, (iv) utilising stress-tolerant crop cultivars and restoring degraded soils, (v) promoting carbon sequestration through alternate production technologies and land use, and (vi) conserving ecosystems to ensure food security. Reliable and effective early warning systems for changes in the climate, and policies to support the transfer of information can benefit farmers, agriculture-dependent industries, and policymakers by motivating them to take precautionary measures to avoid significant losses. It is also necessary to formulate both short- and long-term policies for the development, nourishment, and protection of natural resources. Capacity building through local, national, and international collaboration amongst farmers, policymakers, and the scientific community is necessary. The monitoring and evaluation of adaptation processes, investments, and results are crucial for evidence-based decision making and adaptation capacity enhancement in agriculture. Policy frameworks that support disaster risk reduction and climate change adaptation must be made robust to avoid maladaptation, taking into account the linkages of the various agricultural sectors (crops, livestock, and fisheries) with each other, as well as with additional sectors and policy domains such as irrigation, economy, gender, and social protection.

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