Chapter 11

Ensuring Food and Nutritional Security in the Face of Disasters and Climate Change: What is the Adaptive Solution?

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CHAPTER 11

Ensuring Food and Nutritional Security in the Face of Natural Disasters and Climate Change: What are the Adaptation Solutions?

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11.1 Introduction

According to the Food and Agriculture Organization of the United Nations (FAO), 'food security exists when all of the people, at all times, have physical, social and economic access to sufficient, safe and nutritious food, in order to meet their dietary needs and food preferences for an active and healthy life' (FAO, 1996). The FAO also identified availability, access, utilisation, and stability as four pillars of food security (FAO, 2008). Food security is influenced by several factors such as rising demand, higher commodity prices, soil degradation, climate change, and natural disasters, which cause food insecurity. On the other hand, food insecurity is defined by the United States Department of Agriculture (USDA) as the limited or uncertain availability of nutritionally adequate and safe foods or the limited or uncertain ability to acquire acceptable foods in socially acceptable ways (Bickel et al., 2000). The majority of the world's food insecure people live in countries that are prone to natural hazards and climate change. These people mostly depend on agriculture for a living. They have a significantly low asset base, which might increase the risk of exposure to natural disasters and climate change (FAO, 2015).

Natural disasters and climate change represent major risks for long-term food and nutritional security. Natural calamities such as droughts, storms, earthquakes, landslides, and floods occur every year, at any time or place, affecting human life and food security. These threats restrict food production by affecting crop yields, seed reserves, livestock, fisheries, farm equipment, infrastructure, supply systems, and food trade, which can result in economic losses and disrupt the internal equilibrium in vulnerable nations (De Haen, 2008; Sperling, 2008). Natural disasters affected more than 1.9 billion people in developing countries from 2003 to 2013, causing more than $494 billion in estimated losses. Agriculture absorbs about 22% of the aggregate economic impact of natural disasters (FAO, 2015). Beyond production losses, disasters create nutrient insecurity, especially in children, causing stunted growth during droughts and after floods (Silventoinen, 2003; Del Ninno, Dorosh, and Smith, 2003).

Climate change has a range of direct and indirect effects on all four dimensions of food security in countries vulnerable to hunger and undernutrition (Wheeler and von Braun, 2013). It aggravates the risks of hunger and undernutrition in several ways, with direct effects on crop production, livestock, and agroecosystems through warmer temperatures, changes in rainfall patterns, and frequent extreme weather events. Indirect effects include changes in markets, food prices, and supply chain infrastructure demanding more food production. The impact of climate change varies from location to location, depending on the degree of warming and associated changes in rainfall patterns.

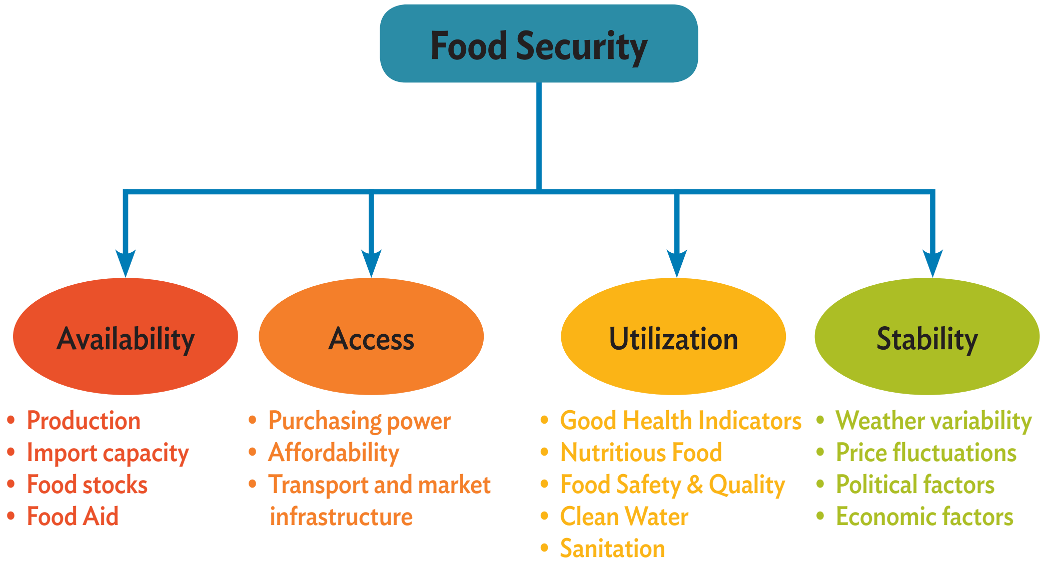
People who are food-insecure usually live in conditions in which a high risk of natural hazards coincides with high vulnerability. The capacity to adapt food production systems to reduce their vulnerability is essential because of the effects of natural disasters and climate change on food security. Adaptation strategies that manage disaster risk reduction and climate-related extreme weather events seek to reduce factors that contribute to the risks, thus supporting and promoting food and nutritional security. Improved systems of food production, distribution, and economic access may all contribute to coping with climate change, but in adopting such changes it will be important to ensure that they contribute to long-term agriculture sustainability (Wheeler and von Braun, 2013). In this chapter, we discuss the effects of natural disasters and climate change on food production, as well as the associated consequences on human food and nutritional security. The following sections also provide an overview of the adaptation strategies that are employed in a range of fields in the context of natural disasters and climate change to achieve food and nutritional security.

11.2 Food Security

11.2.1 Food Security and Components

Food security essentially deals with the constant availability of and access to food, in the appropriate quantity and quality, to meet people's dietary energy requirements (Pinstrup-Andersen, 2009). The most widely accepted definition of food security is that it is a condition in which all people, at all times, have physical, social, and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life (FAO, 1996). Four major pillars of food security are believed to be crucial in accomplishing sustainability: food availability, access, utilisation, and stability (Figure 11.1).

Figure 11.1: Food Security and its Components



Source: Authors.

Availability

This pillar refers to the constant availability of food in adequate quantities. Availability depends on food production; stock; and imports, including food aid (FAO, 2009). It is also associated with factors such as the availability of natural, human, and economic resources.

Access

Access is determined by people's initial ability to produce their own food or their purchasing power. It depends on their resources and opportunities in terms of physical and economic access to food through their own efforts, state interventions, or both.

Utilisation

Utilisation refers to the metabolisation and positive nutritional impact on people. Essentially, food utilisation depends on food preparation, storage, nutrition, food safety, quality, and water and hygiene practices.

Stability

This is the ability to procure food over time, through production and/or food transfer. Stability is usually affected by a lack of production, natural disasters, crop failure, price fluctuations, and civil conflict.

11.2.2 Food Security Score and Prevalence of Undernourishment

Food security focuses on food availability, access, utilisation, the stability of food security over time, or some combination of these domains. Due to the complexity of the factors that contribute to food security and their significance in understanding food security in different contexts, some institutions implement consultative methods for developing food security measurement tools. One such tool is the Global Food Security Index (GFSI), which is multidimensional and uses various indicators for assessing country level trends in food security. The GFSI was designed by the Economist Intelligence Unit and sponsored by DuPont. It uses 28 indicators within the affordability, availability, and quality domains of food security across 113 countries (Economist Intelligence Unit, 2016). Its scores are calculated each quarter based on shifts in food price data. The best and worst GFSI scores of countries are listed in Table 11.1 by region. The country with the highest food security (86.6) score and number one global rank is the United States (US), while Burundi in Africa has the lowest food security score (24.0) (Table 11.1). In Southeast Asia, Singapore has the highest food security score (83.9), ranked third globally, while the Lao People's Democratic Republic has the lowest food security score (32.7) and is ranked 103rd globally (Economist Intelligence Unit, 2016) (Table 11.1 and Table 11.2).

Along with the food security score, the GFSI rank shows the prevalence of undernourishment in all 113 countries. This indicates the percentage of the population that does not meet the required minimum number of calories for an average person stipulated by the FAO along with the World Health Organization and the United Nations in 2001. The lowest and highest rates of prevalence of undernourishment are listed in Table 11.1, with Haiti having the highest prevalence of undernourishment at 53% (Table 11.1). Amongst the Association of Southeast Asian Nations (ASEAN) member countries, Singapore has 0% prevalence of undernourishment while the Lao People's Democratic Republic has 18%. The prevalence of undernourishment for the rest of the ASEAN countries (Table 11.2) was 5%–14% (FAO et al., 2017).

The food security score and the prevalence of undernourishment provide a common framework for understanding the root causes of food insecurity by looking at the dynamics of food systems around the world. Many factors affect and will have significant impacts on food security – the changing climate, growing global population, availability of arable land, water resources, rising food prices, and environmental stressors (Premanandh, 2011).

Table 11.1: Countries with the Best and Worst Food Security Scores in Each Region

Region	Country	Global rank (1 to 113)	Food security score (1 to 100)	Prevalence of undernourishment (%)
North America	US	1	86.6	5
	Mexico	39	68.1	5
Central and South America	Chile	24	74.4	5
	Haiti	108	29.4	53
Europe	Ireland	2	84.3	5
	Ukraine	63	55.2	5
Middle East and North Africa	Israel	17	78.9	5
	Yemen	100	34.0	26
Sub-Saharan Africa	South Africa	47	62.9	5
	Burundi	113	24.0	0
Asia and the Pacific	Singapore	3	83.9	0
	Lao PDR	103	32.7	18

Lao PDR = Lao People's Democratic Republic, US = United States.

Source: Economist Intelligence Unit (2016).

Table 11.2: Food Security Score of ASEAN Countries

Country	Global rank (1 to 113)	Food security score (1 to 100)	Prevalence of undernourishment (%)
Singapore	3	83.9	0
Malaysia	35	69	5
Thailand	51	59.5	7
Viet Nam	57	57.1	11
Indonesia	71	50.6	7
Philippines	74	49.5	13
Myanmar	80	46.5	14
Cambodia	89	39.8	14
Lao PDR	103	32.7	18
Brunei Darussalam	-	-	-

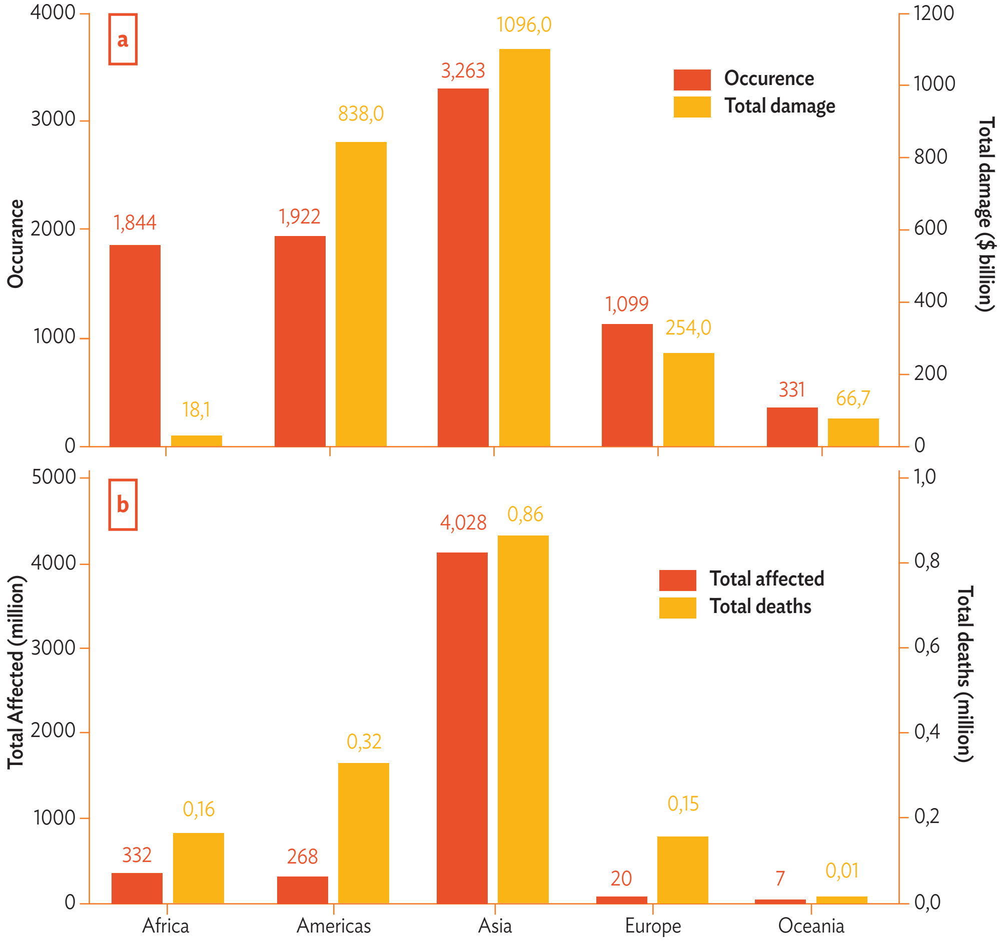
ASEAN = Association of Southeast Asian Nations, Lao PDR = Lao People's Democratic Republic.

Source: Economist Intelligence Unit (2016).

11.2.3 Effect of Natural Disasters on Food Security

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). A natural disaster event often occurs unexpectedly, causing great damage and destruction, devastating local capacity, and demanding external aid at the national or international level. Natural disasters are biological, geophysical, meteorological, climatological, and hydrological. Major factors that account for the increase in the rate and severity of natural disasters are climate change, urbanisation, and environmental degradation. The majority (70%) of the world's disasters take place in low-income countries (Gaire et al., 2016). East Asia and the Pacific are the world's most disaster-prone areas and face increasing risks of natural disasters. The chance of disasters such as earthquakes, landslides, floods, avalanches, and glacial lake outbursts in these regions are high partly because of the Himalayas. People living in the drainage basin of the Himalayan rivers might experience floods and severe droughts in the coming decades (Kim et al., 2015). According to the Emergency Events Database (EM-DAT, 2017), 301 country level disasters occurred in 2016, affecting 102 countries. The effects of 8,459 natural disaster events during 1996–2016 caused up to 1.49 million deaths and affected 4,657 million people, causing damage totalling $2,274 billion in economic losses (Figure 11.2(a) and Figure 11.2(b)). China was the country most affected by natural disasters, with 29 events in 2016, which killed an estimated 1,151 people and affected 13 million people (Centre for Research on the Epidemiology of Disasters (CRED), 2016). The Global Climate Risk Index (CRI), developed by Germanwatch, analyses the quantified impacts of extreme weather events in different countries both in terms of fatalities as well as the economic losses that occurred. Based on the 2017 CRI, six countries from Asia (Table 11.3) are in the top 10 lists with long-term high CRI (Kreft, Eckstein, and Melchior, 2016).

Figure 11.2: The Impact of Disasters in Different Continents, 1996–2016



Source: EM-DAT (2017).

Table 11.3: Long-Term Climate Risk Index of the 10 Most Affected Countries, 1996–2015
(annual average)

CRI	Country	CRI score	Total losses ($ million)	Losses per unit of GDP (%)	Number of events
1	Honduras	11.3	568	2.10	61
2	Myanmar	14.2	1,300	0.74	41
3	Haiti	18.2	221	1.48	63
4	Nicaragua	19.2	234	1.19	44
5	Philippines	21.3	2,761	0.63	283
6	Bangladesh	25.0	2,283	0.73	185
7	Pakistan	30.5	3,823	0.65	133
8	Viet Nam	31.3	2,119	0.62	206
9	Guatemala	33.8	401	0.47	75
10	Thailand	34.8	7,574	1.00	136

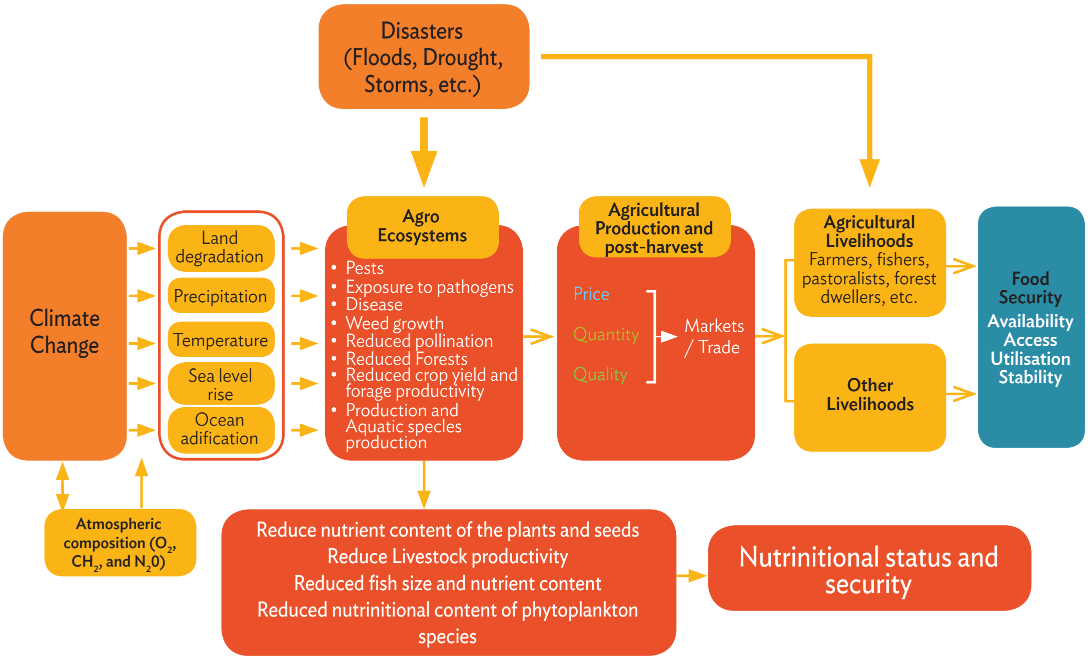
CRI = Climate Risk Index, GDP = gross domestic product.

Source: Kreft, Eckstein, and Melchior (2016).

Natural disasters are a leading cause of food insecurity. They affect all components of food security, reducing economic and physical access to food availability, utilisation, and stability. They also affect agroecosystems by causing losses in crop production, fisheries, and livestock. Natural disaster events may spread diseases and make it difficult to control pests (Figure 11.3). It is fundamental to manage agriculture systems to preserve ecosystem services, such as their capacity to ensure food security. The intensity and frequency of climate-related natural disasters is projected to increase. Poor people, including many smallholder farmers and agricultural workers, are more vulnerable to the impacts of such disasters. Severe droughts or floods can sharply reduce incomes and cause asset losses, which erode future income-earning capacity. Food supply chains are also affected by natural disasters, with an effect on food prices. For example, the value of the FAO Food Price Index more than doubled from 2002 to 2011, suggesting a continuous rise in agricultural commodity prices since 2002. This was due to the occurrence of three droughts in Australia from 2001 to 2007, a heatwave during the summer of 2010 in central Asia, and other calamities (Caldecott et al., 2013).

No significant effect of natural disasters on overall gross domestic product (GDP) was observed using 5-year growth averages during 1961–2005. However, the impact of droughts was negative while the impact of floods was positive. The positive effect of the floods may be due to the availability of water after floods – benefiting the crops, balancing the localised damage from flooding, and providing additional nutrients carried from uplands to lowlands (Israel and Briones, 2012). Floods also temporarily create a larger water habitat for inland fish and other aquatic animals. This positive effect can disappear in the case of more severe flooding, however, which can damage farm infrastructure, supplies, facilities, and stored seeds (Loayza et al., 2012). The differing impacts of natural disasters usually depend on the type and severity of the disaster (Fomby, Ikeda, and Loayza, 2013). For instance, the detrimental effect of droughts on crops caused production losses of about 90% in sub-Saharan Africa where the agriculture sector on average contributes a quarter of GDP. Total crop and livestock production losses after major droughts were equivalent to more than $30 billion during 1991–2013 in this region (FAO, 2015).

Figure 11.3: Overview of Impacts of Natural Disasters and Climate Change on Food and Nutritional Security

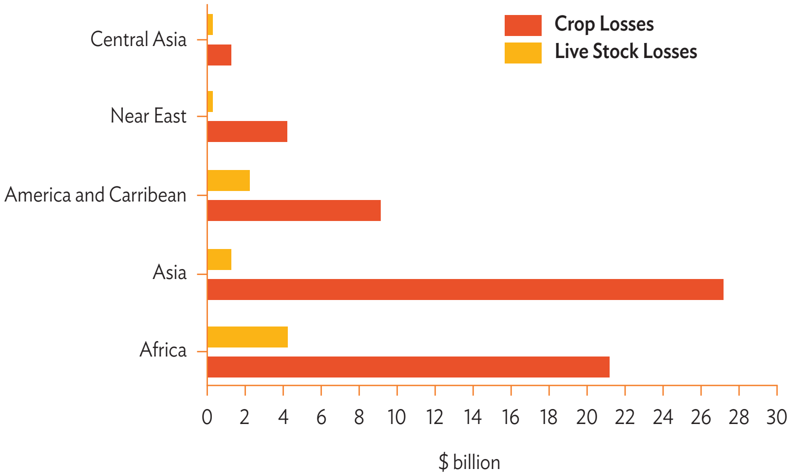


Source: Authors (modified from FAO, 2015).

A statistical analysis using FAO agricultural databases helped to quantify crop and livestock production losses, as well as changes in trade flows and the performance of agriculture value-added growth. The analysis considered 140 medium- and large-scale disasters from 2003 to 2013 which occurred in 67 developing countries, affecting at least 250,000 people (Figure 11.4 and Figure 11.5). The disasters resulted in losses of about $80 billion, which are mainly due to damaged agriculture production including crop yields and livestock production. The majority of the agriculture production losses accounts for the reduction in the crop yield. Asia had major crop losses, with production losses of about $27 billion, followed by Africa with $21 billion in crop losses (Figure 11.4). Disasters also caused major livestock losses in Africa, amounting to about $4 billion. Central Asia experienced the lowest crop losses as a result of disasters during 2003–2013, at $1 billion, and zero livestock losses. The production losses correspond to 333 million tonnes of cereals, pulses, meat, milk, and other commodities. This is equivalent to about 7% of national per capita dietary energy supply after each disaster. These losses are significant at the national level and highly significant at the regional level. The estimated losses in calories increase the chance of household food insecurity, and appropriate measures need to be taken to compensate and fill the gap in dietary energy supply (FAO, 2015).

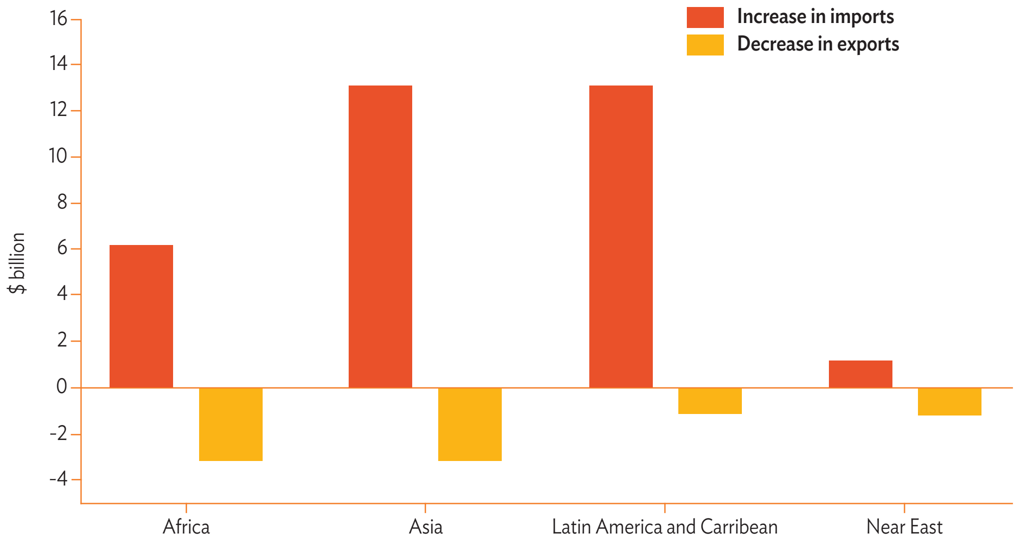
Agricultural and livestock production losses after natural disasters can induce changes in agricultural trade flows, which can increase imports and decrease export revenue – affecting countries' economies. The disasters analysed were closely correlated with rises in food imports and drops in food exports. Asia was found to have the highest increase in imports and decrease in exports (Figure 11.5). Increases in imports amounted, in relative terms, to 28% of their projected value, while decreases in exports represented about 6% of the projected value of exports. Expenditure caused by higher imports and lower export revenues can negatively affect the national balance of payments, the economy, and GDP. The analysis also revealed significant negative trends in agriculture value-added growth for 55% of the disasters considered. Each disaster was followed by an average loss of 2.6% of national agricultural value-added growth in the countries affected, with a much more significant impact likely at regional levels (FAO, 2015).

Figure 11.4: Crop and Livestock Losses by Region, 2003–2013



Source: FAO (2015).

Figure 11.5: Changes in the Trade Flow of Agricultural Products after Major Disasters by Region, 2003–2013



Source: FAO (2015).

11.2.4 Effect of Natural Disasters on Nutritional Security

The significant influence of disasters on crop yield, livestock, and fisheries also lowers the nutritional quality of food as an outcome in the long term (Figure 11.3). This is a problem in both developing and developed nations, where deficits in the availability and quality of food lead to hunger (Cutter, 2017). This can rapidly turn into a food and nutrition crisis, causing a major impact on children, from which it takes many years to recover. Poor nutrition and lack of clean water keep people in cycles of hunger and poverty, preventing them from achieving sustainable development and recovery. The loss of assets caused by disasters, as well as poverty, affect families' ability to pay for nutritious food and healthcare. This prevents children from reaching their growth potential, resulting in stunted growth, a reduced life span, and low levels of education (Gaire et al., 2016). Studies have shown the influence of disasters on nutrition – causing severe detrimental impacts, especially during the drought season. Empirical evidence shows that children born during a drought are most likely to face malnourishment. For instance, children born in drought-affected areas of Ethiopia are 35.5% more likely to be malnourished and have a 41.0% chance of being stunted. This was also observed in Kenya, where children born in drought periods have a 50.4% likelihood of being stunted and a 71.1% probability of being severely stunted. Malnourishment was found to be even worse amongst preschool children, with more than double the negative effects (Fuentes and Seck, 2007). A high prevalence of undernourishment in children was observed in Ethiopia during drought periods (Delbiso et al., 2017); the Philippines after typhoons (United Nations Children's Fund (UNICEF), 2011); India after floods (Rodriguez-Llanes et al., 2016); and Nepal after an earthquake (Gaire et al., 2016).

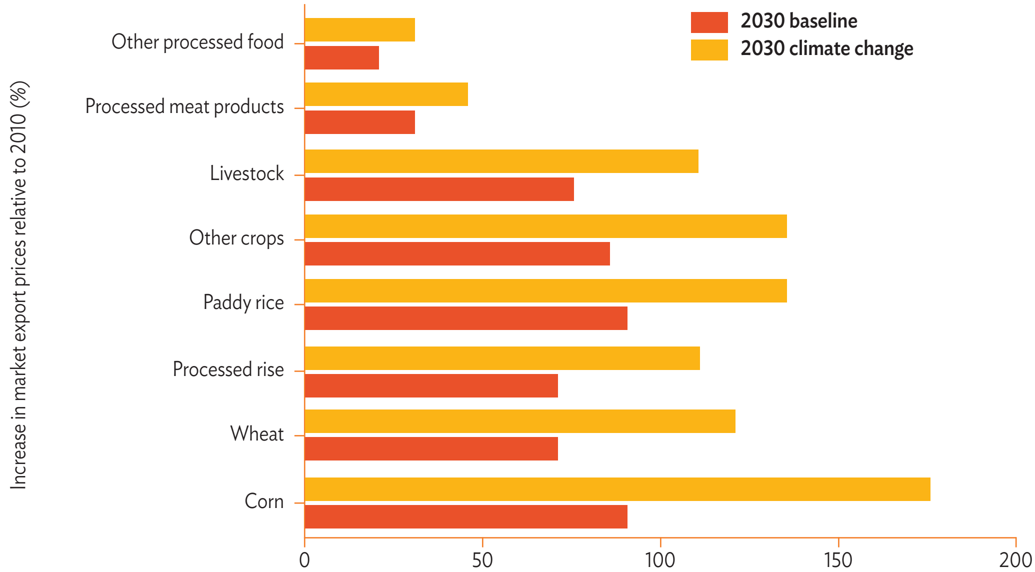
11.2.5 Effect of Climate Change on Food Security

Climate change has resulted in an increase in the global mean temperature and variations in regional precipitation, and these changes are expected to continue and intensify in the future (Solomon et al., 2007). The Intergovernmental Panel on Climate Change (IPCC, 2008) has predicted that climate change over the next century will modify river flows and sea levels throughout the globe, with an effect on rainfall. Researchers show that agriculture yield will likely be severely affected over the next century because of unusual rates of change in the climate system (Jarvis et al., 2010; Thornton et al., 2011). Change in the climate also alters the relationships amongst crops, pests, pathogens, and weeds. It declines the crop yield by influencing the pollinating insects, increasing water scarcity, increasing ground-level ozone concentrations, and decreasing the production of fisheries (Myers et al., 2017) (Figure 11.3). Despite the yield benefits caused by higher carbon dioxide (CO_2) in some crops, the higher temperature caused by increased CO_2 reduces the overall crop yield. Crop growth models – which study the effects of CO_2 combining with temperature, water availability, and limited nitrogen – predict average yield losses of 25% for maize and 15% for wheat if global temperatures increase by 4°C by 2100 (Rosenzweig et al., 2014; Reddy, Singh, and Anbumozhi, 2016). The changes in production caused by climate change are likely to affect food commodity prices, making it difficult to buy in vulnerable countries. Based on the simulation studies, average world market export prices will rise by a higher percentage in 2030 with climate change than without climate change (Figure 11.6), calculated against 2010 export prices (Willenbockel, 2011).

An increase in CO_2 concentrations alters the strength of plant defences against pests and pathogens (Zvereva and Kozlov, 2006). Extreme weather events caused by climate change can threaten agricultural production, compromising crop defences which permit pests and weeds to become established (Rosenzweig et al., 2001). There is an indication that rising CO_2 favourably selects invasive, noxious species of weeds within plant communities, stimulating their growth and making them difficult to control (Ziska and George, 2004). Climate change will also affect the abundance and distribution of pollinating insects, which may reduce the chances of pollination of flowering plants, lowering their production (Hegland et al., 2009).

Global sea level rise from glacier melting, caused by 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). For example, in Asia and North Africa, where the most vulnerable people live in the river deltas of Bangladesh, India, Egypt, Myanmar, and Pakistan, farming areas in coastal regions are exposed to sea level rise (Webster, 2008). Most of the population in these countries depend on farming and fishing, so the rise in sea levels will have an impact on their livelihoods. Rising sea levels also cause destructive erosion, wetland flooding, soil contamination, and lost of habitat 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).

Figure 11.6: Projected Increase in Market Export Prices of Different Food Commodities in 2030 Relative to 2010 – With and Without Climate Change



Source: Willenbockel (2011).

Climate Change and Pillars of Food Security

Several studies focus on understanding the sensitivities of agriculture to climate change. However, assessments of climate change effects on food security remain limited. While discussing food and nutritional security, it is essential to discuss access, utilisation, and stability rather than only availability (which basically deals with production).

Food Availability

As discussed in section 11.2.5, changes in climatic conditions have an effect on the production of some staple crops, livestock, and fisheries. Future climate change predictions threaten to intensify this effect, with more projected losses. Warmer temperatures will impact the crop yields while changes in rainfall could affect both crop quality and quantity. This reduced agricultural production in some vulnerable countries will affect dietary diversity and nutritional security.

Food Access

The decrease in yields resulting from climate change could increase the price of major crops in some regions. Lower agricultural output will result in lower incomes. The drop in income and increased food prices will make it difficult to access food, especially for vulnerable communities.

Food Utilisation

Inadequate calorie intake and protein, predominantly in areas where chronic food insecurity is already a significant problem, create vicious cycles of disease and hunger. This leads to reduced dietary diversity, poor sanitary practices, and health problems.

Food Stability

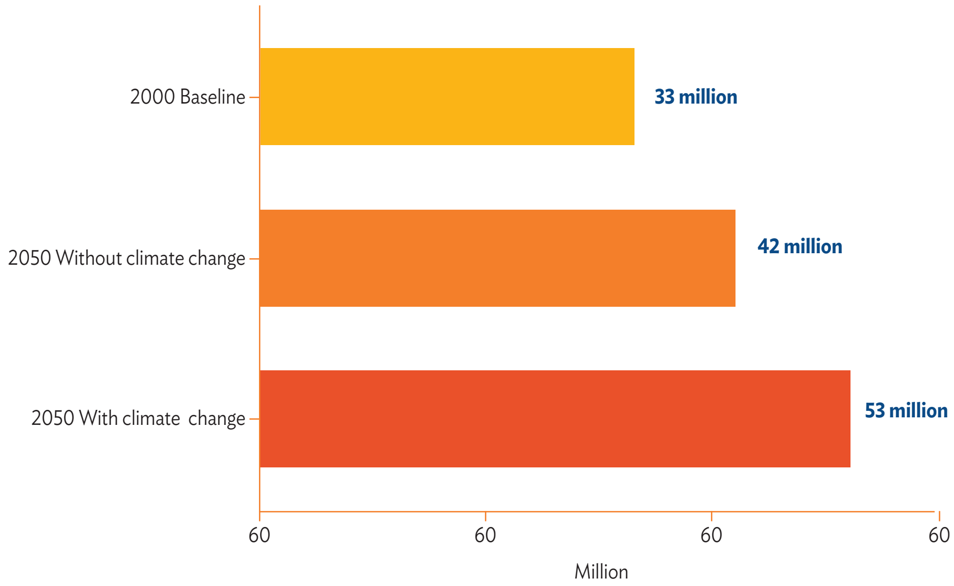
Extreme weather events can discourage the stability of people and governments' food security strategies. Agricultural production losses usually create instability in agricultural income and thus food supply chains.

11.2.6 Climate Change Effects on Nutrition

The increased CO_2 resulting from climate change can modify seed protein and mineral composition. It will also have an effect on the nutritional quality of livestock and aquatic animals (Chavez, Messié, and Pennington, 2011; Myers et al., 2014). The intake of food with low nutritional quality leads to nutritional insecurity in adults as well as children, with a high impact. Climate change could aggravate undernutrition, e.g. inadequate calorie intake caused by the unavailability of food could affect human health. Undernutrition usually increases people's susceptibility to and the severity of infectious diseases and thus ill health. Low availability of food and low calorie intake cause changes in health conditions and can lead to stunted growth and marasmus in children.

Inadequate healthcare practices could be intensified by the lack of clean drinking water and poor sanitation. The possible rise in food prices caused by climate change could reduce dietary diversity and hence the nutritional value of the diet. Simulation studies suggest that the number of people at risk of hunger in sub-Saharan Africa will increase by 10%–20% by 2050 compared with 2000. This accounts for 65% of the population of sub-Saharan Africa. The number of malnourished children could increase by up to 21% (Nelson et al., 2009) (Figure 11.7).

Figure 11.7: Projected Number of Malnourished Children in Sub-Saharan Africa in 2050



Source: Nelson et al. (2009).

11.3 Adaptation Strategies

11.3.1 Disaster Risk Management

It is important to consider both proactive and reactive measurements to achieve food security in the face of disasters. Proactive measurements are to anticipate disaster risks in development investments, by enhancing resilience before a disaster occurs. Reactive measurements are to take disaster risk as a given, invest in normal development, and repair the damage after a disaster. As defined by the UNISDR, disaster risk management 'is the systematic process of using administrative directives, organisational and operational skills and capacities to implement strategies, policies and improved coping capacities in order to lessen the adverse impacts of hazards and the possibility of disaster' (UNISDR, 2009). Most natural disasters cannot be avoided, even with preventive measures, and the risk cannot be reduced to zero (World Bank, 2014). Hence, it is important to maintain definitive risk management strategies to mitigate natural disasters where risk cannot be avoided.

In any case, investing in resilience needs to be seriously considered and the benefits and costs need to be assessed. According to the Department for International Development of the United Kingdom (DFID), resilience necessitates social, institutional, and informational resources that allow a community to respond effectively to a disaster impact. It also includes early warning systems, monitoring, and evaluation for enhanced coping and adaptation (DFID, 2004). Disasters can greatly affect all four dimensions of food security because of the wide range of their impacts. Specific implications for food security depend on whether a disaster affects the availability of food, the physical and financial access to food, or both. During disasters, the extent of the shortfall in food availability depends on local food availability, access to regional food reserves, and food assistance from national and international organisation.

However, people in a remote area with a transportation system damaged by disasters often suffer significant shortfalls in food availability. The main objective of disaster risk management is to reduce the natural disaster risk impact and build resilience to food security, making food available to affected people. Some proactive and reactive measures to manage the disaster risk for food security are listed in Table 11.4.

Table 11.4: Proactive and Reactive Measures of Disaster Risk Management

PROACTIVE
Early warning: Monitor for natural disasters (weather forecasting)
Standardisation, coordination, and monitoring of food security data
Strengthen the capacities of countries to reduce hunger
Improve food storage for emergencies
Identify the nature of the disruptions (water, food storage) and better infrastructure to protect food reserves
Strengthen disaster preparedness for effective response at all levels
REACTIVE
Save lives in emergencies and minimise the immediate impact of disasters on food-insecure populations
Restore and rebuild lives and livelihoods in post-disaster situations by rebuilding livelihood assets and infrastructure to improve access to food
Work together with affected communities to recover
Build resilience to reduce long-term effects and withstand the impact of future disasters
Reduce chronic hunger and undernutrition to lessen the enduring impact of disasters, especially on children, by providing nutritious food
Focus on improving the nutritional status of food-insecure people

Source: Authors.

11.3.2 Adaptation Strategies to Natural Disasters and Climate Change for Food Security Management

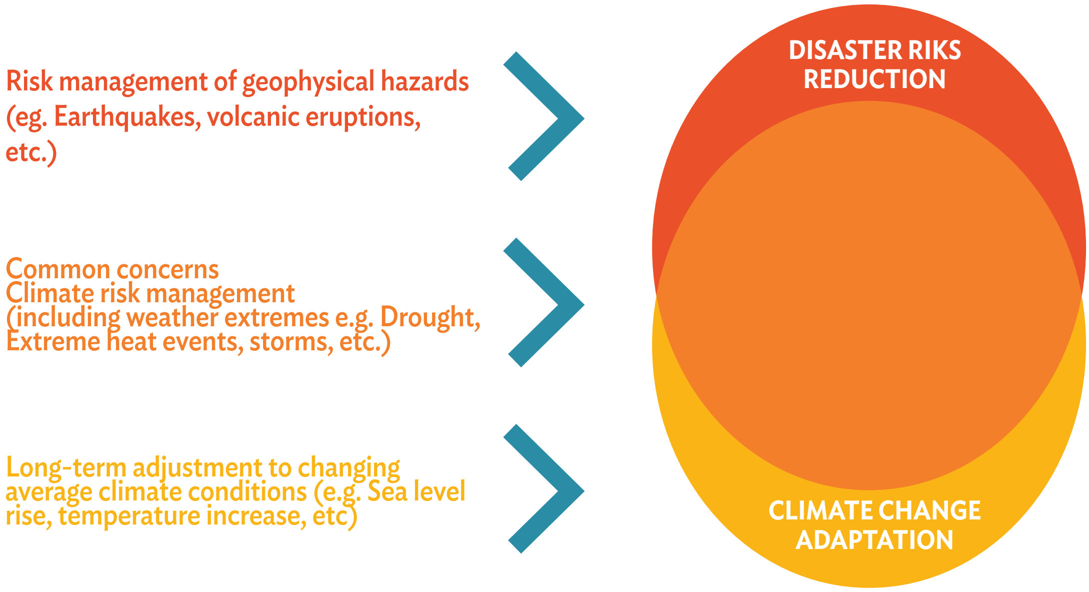
Global warming resulting from climate change is projected to increase the frequency and intensity of natural disaster risks by altering average climatic conditions, worsening climate variability, increasing extreme weather events, and posing greater overall risks for people in developing countries. Climate change is projected to result in decreased water availability and crop productivity in many parts of the world, as well as the loss of plant and animal species and associated ecosystem services. Every year, natural disasters and climate-related extreme events cause a substantial loss of life, economic damage, and social development.

Adaptation is a key 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 risk 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). An increase in disaster preparedness to manage risk also ensures climate change resilience. Both disaster risk reduction and climate change adaptation practices involve learning to deal with existing and projected future risk.

Several frameworks and strategies provide an integrated approach to disaster risk reduction and climate change adaptation. Natural disaster risk reduction and climate change overlap where there are common concerns such as drought, extreme heat events, floods, and storms (Figure 11.8). Adaptation strategies to implement disaster risk reduction should be established based on the evaluation and prioritisation of the risks that people face, as well as their ability to adapt to and resist the effects of those risks.

Below, we discuss different adaptation strategies and frameworks for climate change and disaster risk management for food and nutritional security.

Figure 11.8: Overlap between Climate Change Adaptation and Disaster Reduction Risk



Source: Birkmann and von Teichman (2010).

Monitoring, Evaluation, and Early Warning

In the developing world, the majority of the population depends on climate-sensitive sectors, such as agriculture and forestry, for their livelihoods and nutrition. The vulnerability of these countries is further increased by their limited capacity to assess climate risks and the lack of available weather information required to plan adaptive responses. Weak infrastructure, poor communication networks, intermittent electricity supply, low public awareness, and insufficient resources obstruct the provision of timely advice for early disaster warnings. Without such information, a proactive approach to risk management cannot be fully implemented. Understanding the multifaceted nature of both exposure and vulnerability is a prerequisite for determining how weather and climate events contribute to the occurrence of disasters, and for designing and implementing effective adaptation and disaster risk management strategies.

Disaster management usually depends on the source of information, monitoring, and early warning (Eiser et al., 2012). Improving the components of the monitoring helps to evaluate the situation and plan accordingly. Preparation based on monitoring, evaluation, and early warning will reduce possible effects of the extreme natural disaster events and save lives. Along with weather monitoring, it is essential to monitor food reserves in case of emergencies and be prepared for disasters. For better disaster risk reduction and climate risk management, evaluation of the possible impacts on crops, livestock, and fisheries is important. The measurements in food security management include livestock shelters, animal fodder reserves, bags for smallholder farmers to store seeds, improved seed storage facilities, raised seedbeds, and strategic animal fodder reserves.

Optimising Production

Natural disasters and climate change have a substantial effect on agricultural production – affecting food and nutritional security. Production gaps can be reduced through interventions such as better management of seeds, nutrients, and water. To optimise agricultural production, several knowledge-intensive forms of agriculture provide the technology and encouragement to make it feasible for farmers to accept and adapt them (Nelson, 2009). Preliminary study results by the FAO (2017) indicated that the combined application of several mutually reinforcing good practice technologies in the crop sector leads to economic benefits that are more than four times higher with respect to usual practices in disaster-prone areas. These include a combination of agronomic practices for soil and water management, infrastructure improvement, equipment for disaster risk management, and research and development for adapted crop seeds and technologies. The following are some of the strategies recommended to optimise agricultural production and secure food in case of disasters and climate change.

Communication and Technologies

Information and communication technology allows researchers to provide information and data to those who need it in a timely manner (Toya and Skidmore, 2015). As a result, decision makers and farmers are better equipped to make informed decisions about cropping schedules, water use, and disaster risk management. The use of satellites to measure the moisture level of the soil (especially after flooding) and monitor groundwater will improve the knowledge of water levels and give farmers choices regarding crop timing and varieties. This satellite information is usually available to the public via websites or apps. Some organisations are trying to provide hotline services for farmers in developing countries to reach, warn, and prepare farmers for extreme weather events (Kaur et al., 2015).

Adaptive Crop Varieties and Diversification

Drawing on indigenous knowledge and experience, smallholder farmers have responded to environmental changes in the past with gradual changes in their agricultural practices and the selection of adapted cultivars, and by mixing crops with trees and livestock to reduce the risk of crop failure (Ortiz, 2011; Sthapit, Padulosi, and Mal, 2010; Lasco et al., 2014). Nowadays, the adoption of 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 have been found to be some of the most common adaptation measures adopted by farmers in response to climate change (Altieri and Koohafkan, 2008; Verchot et al., 2007). Diversification is considered the best strategy for optimising crop production. In terms of agriculture, diversification is basically the addition of new crop varieties or livestock strains (Reddy and Anbumozhi, 2017). Several drought, salinity, and heat-tolerant varieties have been released by national and international agricultural research organisations. Choosing drought- and heat-tolerant varieties in drought and high temperature areas will increase production. The introduction of new varieties such as legumes through diversification improves soil fertility, assists in the consumption of proteins, and diversifies people's diets (Headey and Kennedy, 2012). In the case of livestock, trying new strains will be useful. Overall, diversification can offer resilience to agricultural systems.

Farm Practice Technologies

Farm practice technologies include soil and water management to optimise crop productivity. Alternative water resources, new irrigation techniques, and expanding irrigation help in handling drier climates. For example, watering and fertilisation through drip irrigation can reduce the environmental impact of irrigation and fertiliser application. Micro-irrigation or low-pressure irrigation systems – coupled with water filters, smart meters, and solar-based irrigation pumps – helped to deliver water and nutrients directly to the root zone of crops in sub-Saharan Africa. This has resulted in highly efficient use of resources to achieve high yields (Burney and Nolan, 2012). Farm practice methods involve crop varieties that use water efficiently (more yield/water used), drip or low-pressure irrigation systems to water crops, and lining waterways (canals/pipes) to decrease water losses in delivery systems and help target the water where it can be used most effectively (Pittman et al., 2011). The use of mulching and trenching, organic fertilisers, and organic pesticides will make the crops more resistant to climate constraints and improve productivity (FAO, 2017).

Farm Infrastructure

Participating in small-scale agricultural infrastructure is important for improving the resilience of smallholder farmers in risk-prone areas. In the livestock sector, building animal shelters to protect animals from extreme temperatures and disasters is one of the strategies. In the case of farming, rooftop water harvesting and water storage tanks are used to ensure the availability of necessary resources before or after a disaster (FAO, 2017).

Ecological Restoration

Integrating adaptation strategies and attributes could help improve ecosystem restoration and monitoring efforts under climate change. Ecosystem restoration can hasten adaptation to future climate change and disaster impacts by re-establishing the processes which promote natural variability and biodiversity within ecological systems (Hansen, Biringer, and Hoffman, 2003). Successful ecological restoration requires institutional frameworks to ensure that all stakeholders have fair access to benefits from the natural resources on which they depend for their livelihoods. Participating primarily in forest landscape restoration and ensuring proper management planning is vital. With the appropriate resources and policies, decentralising power and transferring resource management responsibilities to local communities can achieve sustainable success for restoration and sustainable agriculture (Kumar et al., 2015). Adaptation strategies for ecological restoration – including crop improvements, soil conservation, conservation agriculture, forest conservation (e.g. mangrove conservation), sustainable forest management, integrated pest management, livestock and fodder crops and fisheries management, and coral restoration – are based on ecosystems and minimise the scope for maladaptation in developed and developing countries (Keys and McConnell, 2005; Pretty, Toulmin, and Williams, 2011). Ecological restoration will have the potential to conserve the natural assets of agriculture through farmland improvement and ecosystem management (Reddy and Anbumozhi, 2017). Other ecological restoration practices include agroforestry activities such as planting trees, climate-smart landscapes, communal gardens, intercropping, and livelihood diversification in disaster-prone areas. Trees conserve soil and water; add nutrients to local diets; and provide materials for fodder, construction, and fuel. The restoration and development of ecosystems also minimise greenhouse gas emissions. Thus, the tree species chosen to restore communal areas must be able to meet a variety of environmental, social, and economic needs (Kumar et al., 2015). The strong relationship between soil health and food security calls for strategic and immediate action, especially at the local level, to reverse soil degradation in order to increase food production and alleviate food insecurity in the areas where it is most prevalent.

Food and Seed Reserves

The effects of climate shocks on national and regional food markets may also have consequences on humanitarian food assistance, government food reserves, and safety net programmes. Providing food is essential in times of need, especially in critical situations following storms, earthquakes, floods, drought, or other disaster emergencies. Investments are needed to establish and operate strategic food reserves as a means to balance food supply and demand, and ensure the availability of and access to food during a crisis. The purpose of food reserves is to provide emergency food assistance to transitory food-insecure households, support communities and farmers with storage facilities, assist producers in securing fair prices at harvest times, and contribute to domestic food price stabilisation (World Food Programme (WFP), 2015). Local food reserves specifically designed for emergency response are useful in situations of delayed assistance at the national and international level, and can be a temporary food support.

Another strategy is building a household seed storage facility or improving facilities to store seeds at home. Monsoon rains destroyed seeds after the earthquakes in Nepal (Dey, 2015) and Haiti (McGuire and Sperling, 2013) and following the floods in Pakistan (Doocy et al., 2013). Storage structures built in houses or mud granaries become wet during floods and spoil the stored seed, resulting in the loss of livelihoods (McGuire and Sperling, 2013). This damage destroys the local seed supply mechanism, making farmers vulnerable to seed crisis in the long term. Distributing inexpensive low-oxygen grain storage bags to the affected areas during emergencies could help farmers to store and save seed temporarily (Chapagain and Raizada, 2017). Developing community seed banks could provide repositories of local genetic diversity, which is often adapted to prevailing climate conditions, including biotic stresses.

Capacity Building

Capacity building is the process in which individuals, groups, organisations, institutions, and societies increase their competencies to perform core functions, solve problems, and define and achieve objectives. Capacity building is also useful to understand and cope with development needs in a broad context and a sustainable manner (Alcayna et al., 2016).

Experts are increasingly aware that building capacity efforts for food security involves enhancing the ability of individuals, groups, organisations, and communities to meet their food and nutritional security challenges sustainably. This cannot be successful in the long run without well-qualified local individuals and institutions to provide appropriate incentives for, motivate, and manage these efforts. It requires developing skilled, creative, and motivated individuals – and establishing effective institutions, both governmental and non-governmental – to engage people in problem solving. It entails fostering teamwork amongst farmers, extension agents, and scientists; and often amongst different government ministries and nations (Alcayna et al., 2016).

Local capacity building is also an essential and effective task, and there is a strong need to evolve proactive and reactive strategies (Table 4) and bring together diverse groups of people in relevant efforts to support adaptation capacities to mitigate the effects of natural disasters and climate change. Differences in community resources, livelihoods options, and assets affect local capacity and the extent to which capacity can be strengthened (Uy, Takeuchi, and Shaw, 2011). A case study in Iloilo City showed that community-driven disaster risk management required strong social networks, alternative finance facilities, technical professional networks that support community processes, and community-managed information systems (Carcellar, Co, and Hipolito, 2011). It has also been emphasised that schools and student groups could play an important role in capacity building for disaster and climate risk management (Fernandez and Shaw, 2015). Local communities are the first to respond when a disaster happens. Therefore, enhancing the disaster management capacity of the communities and local governments is the most effective way to improve disaster management and cope with disasters and the changing climate.

Financial Instruments

Managing the risk of extreme weather events and natural disasters to advance climate change adaptation through risk transfer is one of the adaptation strategies (IPCC, 2012). Financial instruments usually include insurance, government-managed contingency finance devices, and subsidies. Many policymakers and researchers agree that insurance, along with other financial instruments, plays a vital role in lessening exposure and vulnerability and enhancing resilience to the potential adverse impacts of climate extremes (IPCC, 2012). The United

Nations Framework Convention on Climate Change states that sharing and transferring risk through financial instruments will help people in developing and vulnerable countries to address climate change impacts (United Nations Framework Convention on Climate Change, 2013). Another study suggests that financial instruments such as risk sharing and transfer help to distribute the damage and loss caused by extreme weather events and disasters but do not play a role in reducing them (Linnerooth-Bayer and Hochrainer-Stigler, 2015). Basically, financial instruments support lessening the burden on the affected people where the reduction of losses by natural disasters and climate change can be expensive or impossible (Linnerooth-Bayer and Hochrainer-Stigler, 2015).

In the case of high-risk disaster events, people mostly depend on financial instruments such as government managed contingency and donor assistance offer relief. Austria has premium support (paid by income and corporate taxes) from a government relief programme to insure against natural disasters (Raschky and Weck-Hannemann, 2007). Other financial instruments for farmers are pre-disaster savings and post-disaster credit, which for the poor can take the form of stockpiles of food, grains, seeds, and exchangeable assets. This type of financing can be used only where the risk is medium. In the Philippines, a study indicated that pre-disaster savings or micro-savings supported women's economic empowerment, including decision-making power over purchases, family planning, and children's education (Ashraf et al., 2006). This enables the poor, smallholders, and most vulnerable farmers to make investments that increase their profitability.

Microfinance is another financial resource to encourage investments to farmers. It permits farmers to help themselves from potential disaster shocks to the production of crops, livestock, and fisheries (Morduch and Johnston, 2007). In adverse conditions caused by disasters and climate change, microfinance supports farmers through automated insurance payouts which encourage them not to sell their assets and livestock (Reddy and Anbumozhi, 2017). Public policymakers are encouraged to focus on government assistance regimes.

Food Security Governance

One of the adaptation strategies for natural disasters and climate change is adjusting institutional structures and arrangements that facilitate national and local strategies, plans, and financial investments in favour of food security to disaster and climate change. Achieving adaptation at the global, national, and regional levels requires strengthening of the governance system to coordinate adaptation issues. This includes suitable national food security policies and legislative frameworks which involve cooperation between the public and private sectors in creating incentives, supporting activities, and policies that encourage risk reduction and climate change adaptation. Prioritising initiatives at the regional level, such as technologies that strengthen the resilience of farming systems to disasters, could help achieve sustainable agriculture through policy support.

Strengthening the relationship between policymakers, the scientific community, and professionals from all food-related sectors help in developing new decision support systems which can shape the capacity of farmers, fishers, and forest-dependent people to adapt their livelihoods to climate change and disasters (FAO, 2012). The migration of large groups of refugees, who have to leave their habitats because of changes in their natural environment as a result of sea level rise, extreme weather events, and drought and water scarcity, is expected by several researchers. In light of the climate migration crisis, preparing for the protection and resettlement of refugees is recommended through global governance (Biermann and Boas, 2010).

11.4 Adaptive Strategies to Nutritional Security

Natural disasters and climate change not only influence the crop yield but also the nutritional quality of food (Figure 11.3). High rates of malnutrition are considered the outcome of food insecurity in extreme weather events. Plants grown at elevated CO_2 conditions showed a reduction in their protein and mineral concentration (Myers et al., 2014; Loladze, 2014). The altered nutritional composition of plants also modifies the nutritional composition of livestock. Disasters and climate change not only influence the nutritional content of crops but also the nutritional composition of phytoplankton and the fatty acid composition of fish (Bermúdez et al., 2015; Chavez, Messié, and Pennington, 2011). Even though the overall effect of natural disasters and climate change on nutritional security varies according to the location and relevant policies, an adequate supply of nutritious food needs to be maintained to ensure human health, especially that of children. A number of strategies can be undertaken within households, communities, and countries to avoid nutritional insecurity. These include monitoring climate-related extreme weather events through early warning systems and preparing for food and nutritional security. Analysis of the dangers of extreme weather events is required for mitigation measures to achieve food and nutritional security. For example, long-term droughts cause aflatoxin contamination in the seeds of several crop species. Aflatoxin is toxic and causes neurological diseases, cancer, and stunted growth in children. Post-harvest handling and seed safety measures avoid aflatoxin contamination in stored seeds (Tirado et al., 2010). Other strategies include focusing on crop nutrient quantity, dietary diversity, maternal and child feeding practices, and children's health (Tirado et al., 2015). A model is required to predict the effects of climate change and extreme weather events on nutritional quality. This would help to breed the optimal crop varieties and livestock strains for adaptation and achieve better nutritional quality.

It is critical to identify promising climate change mitigation strategies that bring benefits in terms of nutritional security. Regional, national, and international educational institutions and researchers should create awareness about the importance of nutrition in vulnerable communities. It is essential to implement current agendas, policy frameworks, and initiatives to align with disaster and climate change adaptation to reduce hunger and undernutrition (Tirado et al., 2015).

11.5 Summary

Natural disasters and climate change affect all four pillars of food security: availability, access, utilisation, and stability. Extreme weather events intensify existing threats to food and nutritional security by decreasing agricultural production. Altered food production, combined with other factors, influences food prices. This affects the ability of poor households to access food markets and could reduce dietary diversity, affecting nutritional quality. Food and nutritional security to natural disasters and climate change requires the design of adaptation strategies which can reduce vulnerability and increase resilience. Adaptation approaches must incorporate actions targeted at climate change resilience and disaster risk reduction, as well as addressing the underlying causes of vulnerability. An integrated approach to adaptation involves disaster preparedness and relief, resilient infrastructure, and new agricultural technologies and farm practices to face disaster and climate change risks.

This chapter discussed various integrated adaptive strategies to natural disaster risk reduction and climate change adaptation to secure food and nutrition in vulnerable countries. These strategies include implementing early warning systems to monitor and evaluate the effect of disasters and climate change on agriculture, related production, and nutrition. It is also essential to optimise production through the diversification of livelihood and agriculture systems. Managing adaptation to achieve food security requires the research and development of new crop varieties and improving agricultural practices. Recommended agricultural practices include adopting tolerant and early maturity crop varieties, improving irrigation for efficient water utilisation, planting communal gardens, improving ecosystems, and using organic fertilisers. The efficient use of resources such as water and nutrients is beneficial, as it reduces input costs and provides some stability in resource supplies. Innovative technologies such as cellular (apps or texts) and satellite technology to monitor soil moisture and provide up-to-date information, as supported by researchers at the regional, national, and international levels, should be used. These technologies could contain a broad range of developments and play key roles in improving adaptation efficiencies. Financial instruments also play important roles in adaptation to natural disasters and climate change for effective risk sharing and transfer. Implementing food security policies to advance adaptive strategies addresses and minimises the adverse impacts of natural disasters and climate change on food and nutritional security.

References

Adams, R.M. (1989), 'Global climate change and agriculture: An economic perspective', *American Journal of Agricultural Economics*, 71(5), pp.1272–79.

Alcayna, T., V. Bollettino, P. Dy, and P. Vinck (2016), 'Resilience and Disaster Trends in the Philippines: Opportunities for National and Local Capacity Building', *PLOS Currents, 8*.

Altieri, M.A. and P. Koohafkan (2008), 'Enduring Farms: Climate Change, Smallholders and Traditional Farming Communities', *Environment and Development Series*, 6, Penang: Third World Network.

Ashraf, N., D. Karlan, and W. Yin (2006), 'Tying Odysseus to the Mast: Evidence from a Commitment Savings Product in the Philippines', *The Quarterly Journal of Economics*, 121(2), pp.635–72.

Bermúdez, R. et al. (2015), 'Long-Term Conditioning to Elevated pCO_2 and Warming Influences the Fatty and Amino Acid Composition of the Diatom *Cylindrotheca fusiformis*', PLOS One, 10(5), p.e0123945.

Bickel, G., M. Nord, C. Price, W. Hamilton, and J. Cook (2000), *Guide to measuring household food security*. Alexandria, VA: USDA. https://fns-prod.azureedge.net/sites/default/files/FSGuide.pdf (accessed 10 July 2017).

Biermann, F. and I. Boas (2010), 'Preparing for a Warmer World: Towards a Global Governance System to Protect Climate Refugees', *Global Environmental Politics*, 10(1), pp.60–88.

Birkmann, J. and K. von Teichman (2010), 'Integrating disaster risk reduction and climate change adaptation: key challenges—scales, knowledge, and norms', *Sustainability Science*, 5(2), pp.171–84.

Burney, J.A. and R.L. Naylor (2012), 'Smallholder Irrigation as a Poverty Alleviation Tool in Sub-Saharan Africa', *World Development*, 40(1), pp.110–23.

Caldecott, B., L. Howarth, and P. McSharry (2013), *Stranded Assets in Agriculture: Protecting Value from Environmental Risks*. Oxford, UK: Smith School of Enterprise and the Environment, University of Oxford. https://www.smithschool.ox.ac.uk/publications/reports/stranded-assets-agriculture-report-final.pdf (accessed 7 February 2019).

Carcellar, N., J.C.R. Co, and Z.O. Hipolito (2011), 'Addressing disaster risk reduction through community-rooted interventions in the Philippines: experience of the Homeless People's Federation of the Philippines', *Environment and Urbanization*, 23(2), pp.365–81.

Chang, C. (2007), *Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (M.L. Parry et al., eds.). Cambridge, United Kingdom (UK): Cambridge University Press.

Chapagain, T. and M.N. Raizada (2017), 'Impacts of natural disasters on smallholder farmers: gaps and recommendations', *Agriculture & Food Security*, 6(1), p.39.

Chaplin-Kramer, R. et al. (2014), 'Global malnutrition overlaps with pollinator-dependent micronutrient production', *Proceedings of the Royal Society, Series B: Biological Sciences*, 281(1794), 20141799.

Chavez, F.P., M. Messié, and J.T. Pennington (2011), 'Marine Primary Production in Relation to Climate Variability and Change', *Annual Review of Marine Science*, 3, pp.227–60.

CRED (2016), '2016 preliminary data - Human impact of natural disasters', *Cred Crunch*, 45. http://cred.be/sites/default/files/CredCrunch45.pdf (accessed 10 July 2017).

Cutter, S.L. (2017), 'The Perilous Nature of Food Supplies: Natural Hazards, Social Vulnerability, and Disaster Resilience', *Environment: Science and Policy for Sustainable Development*, 59(1), pp.4–15.

De Haen, H. (2008), 'Food Security Strategies: Building Resilience Against Natural Disasters', *EuroChoices*, 7(3), pp.26–33.

Del Ninno, C., P.A. Dorosh, and L.C. Smith (2003), 'Public Policy, Markets and Household Coping Strategies in Bangladesh: Avoiding a Food Security Crisis Following the 1998 Floods', *World Development*, 31(7), pp.1221–38.

Delbiso, T.D., J.M. Rodriguez-Llanes, A.-F. Donneau, N. Speybroeck, and D. Guha-Sapir (2017), 'Drought, conflict and children's undernutrition in Ethiopia 2000–2013: a meta-analysis', *Bulletin of the World Health Organization*, 95(2), pp.94–102.

Dey, S. (2015), 'A Devastating Disaster: A Case Study of Nepal Earthquake and its Impact on Human Beings', *IOSR Journal of Humanities and Social Science*, 20(7), pp.28–34.

Doocy, S., E. Leidman, T. Aung, and T. Kirsch (2013), 'Household economic and food security after the 2010 Pakistan floods', *Food and Nutrition Bulletin*, 34(1), pp.95–103.

Economist Intelligence Unit (2016), *Global Food Security Index*. http://foodsecurityindex.eiu.com/ (accessed 10 July 2017).

Eiser, J.R. et al. (2012), 'Risk interpretation and action: A conceptual framework for responses to natural hazards', *International Journal of Disaster Risk Reduction*, 1, pp.5–16.

EM-DAT (2017), The International Disaster Database. Centre for Research on the Epidemiology of Disasters (CRED), Université catholique de Louvain, Brussels www.emdat.be (July 2017)

FAO (1996), *Report of the World Food Summit*, Rome, 13–17 November. http://www.fao.org/docrep/003/w3548e/w3548e00.htm (accessed 10 July 2017).

FAO (2008), *An introduction to the basic concepts of food security*. Rome: FAO. http://www.fao.org/3/a-al936e.pdf (accessed 7 Feb 2019).

FAO (2015), *Agroecology to reserve soil degradation and achieve food security*. Rome: FAO. http://www.fao.org/3/a-i4803e.pdf (accessed 10 July 2017).

FAO (2017), Benefits of farm level disaster risk reduction practices in agriculture*: Preliminary findings*. Rome: FAO. http://reliefweb.int/sites/reliefweb.int/files/resources/a-i7319e.pdf (accessed 10 July 2017).

FAO, International Fund for Agricultural Development, UNICEF, World Food Programme, and World Health Organization (2017), *The State of Food Security and Nutrition in the World 2017. Building resilience for peace and food security*. Rome: FAO. http://www.fao.org/3/a-I7695e.pdf (accessed 7 February 2019).

Fernandez, G. and R. Shaw (2015), 'Youth participation in disaster risk reduction through science clubs in the Philippines', *Disasters*, 39(2), pp.279–94.

Fomby, T., Y. Ikeda, and N.V. Loayza (2013), 'The growth aftermath of natural disasters', *Journal of Applied Econometrics*, 28(3), pp.412–34.

Fuentes-Nieva, R. and P.A. Seck (2007), 'The Short- and Medium-Term Human Development Effects of Climate-Related Shocks: Some Empirical Evidence', in R. Fuentes-Nieva and P.A. Seck (eds.) *Risk, Shocks, and Human Development*. London: Palgrave Macmillan, pp.152–84.

Gaire, S., T.D. Delbiso, S. Pandey, and D. Guha-Sapir (2016), 'Impact of disasters on child stunting in Nepal', *Risk Management and Healthcare Policy*, 9, pp.113–27.

Hansen, L.J., J.L. Biringer, and J.R. Hoffman (2003), *Buying Time: A User's Manual for Building Resistance and Resilience to Climate Change in Natural Systems*. Gland, Switzerland: WWF.

Headey, D. and A. Kennedy (2012), *Enhancing resilience in the horn of Africa: Synthesis of an evidence based workshop*, Washington, DC, 13–14 December. Washington, DC: International Food Policy Research Institute.

Hegland, S.J., A. Nielsen, A. Lázaro, A.L. Bjerknes, and Ø. Totland (2009), 'How does climate warming affect plant-pollinator interactions?', *Ecology letters*, 12(2), pp.184–95.

IPCC (2008), 'Climate Change and Water', *IPCC Technical Paper* VI. Geneva: IPCC. https://www.ipcc.ch/site/assets/uploads/2018/03/climate-change-water-en.pdf (accessed on 7 February 2019).

IPCC (2012), *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaption*. Cambridge, United Kingdom: Cambridge University Press.

Israel, D.C. and R.M. Briones (2012), 'Impacts of Natural Disasters on Agriculture, Food Security, and Natural Resources and Environment in the Philippines', *PIDS Discussion Paper Series*, 2012-36. Manila: Philippine Institute for Development Studies.

Jarvis, A., J. Ramírez Villegas, B. Anderson, C. Leibing, P. Aggarwal, and K. Pramod (2010), 'Scenarios of climate change within the context of agriculture', in M.P. Reynolds (ed.) *Climate Change and Crop Production*. Wallingford, UK: Centre for Agriculture and Bioscience International (CABI) Publishers, pp.9–37.

Kaur, H., A. Tall, S. Mwanga, and J. Kisanga (2015), *Scaling Up Climate Information Services for Farmers and Pastoralists in Tanzania through ICTs and Rural Radio*, CCAFS Workshop Report, Dar es Salaam, 27–28 April. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Copenhagen: CCAFS. https://cgspace.cgiar.org/rest/bitstreams/64438/retrieve (accessed 10 July 2017).

Keys, E. and W.J. McConnell (2005), 'Global Change and the Intensification of Agriculture in the Tropics', *Global Environmental Change*, 15(4), pp.320–37.

Kim, S.E. et al. (2015), 'Overview of Natural Disasters and their Impacts in Asia and the Pacific, 1970–2014', *ESCAP Technical Paper*. Bangkok: United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP). https://www.unescap.org/sites/default/files/Technical%20paper-Overview%20of%20natural%20hazards%20and%20their%20impacts_final.pdf (accessed 10 July 2017).

Kreft, S., D. Eckstein, and I. Melchior (2016), 'Global Climate Risk Index 2017: Who Suffers Most From Extreme Weather? Weather-related Loss Events in 2015 and 1996 to 2015', *Briefing Paper*. Bonn, Germany: Germanwatch.

Kumar, C., S. Begeladze, M. Calmon, and C. Saint-Laurent, eds. (2015), *Enhancing food security through forest landscape restoration: Lessons from Burkina Faso, Brazil, Guatemala, Viet Nam, Ghana, Ethiopia and Philippines*. Gland, Switzerland: International Union for Conservation of Nature.

Lasco, R.D., R.J.P. Delfino, D.C. Catacutan, E.S. Simelton, and D.M. Wilson (2014), 'Climate risk adaptation by smallholder farmers: the roles of trees and agroforestry', *Current Opinion in Environmental Sustainability*, 6, pp.83–8.

Linnerooth-Bayer, J. and S. Hochrainer-Stigler (2015), 'Financial instruments for disaster risk management and climate change adaptation', *Climatic Change*, 133(1), pp.85–100.

Llamas-Clark, E.F. and C. Banwell (2016), 'Understanding Child Nutrition Preservation after an Extreme Weather Event Disaster', in M. Companion and M.S. Chaiken (eds.) *Responses to Disasters and Climate Change: Understanding Vulnerability and Fostering Resilience*. Boca Raton, FL: CRC Press, pp.117–27.

Loayza, N.V., E. Olaberria, J. Rigolini, and L. Christiaensen (2012), 'Natural Disasters and Growth: Going Beyond the Averages', *World Development*, 40(7), pp.1317–36.

Loladze, I. (2014), 'Hidden shift of the ionome of plants exposed to elevated CO_2 depletes minerals at the base of human nutrition', *eLife*, 3, p.e02245. doi: 10.7554/eLife.02245

McGuire, S. and L. Sperling (2013), 'Making seed systems more resilient to stress', *Global Environmental Change*, 23(3), pp.644–53.

Morduch, D. and J. Johnston (2007), 'The Unbanked: Evidence from Indonesia', *Financial access institute (FAI), NYU Wagner Graduate School of Public Service, March*.

Myers, S.S. et al. (2014), 'Increasing CO_2 threatens human nutrition', *Nature*, 510(7503), pp.139–42.

Myers, S.S. et al. (2017), 'Climate change and global food systems: Potential impacts on food security and undernutrition', *Annual Review of Public Health*, 38, pp.259–77.

Nelson, G.C. et al. (2009), 'Climate change: Impact on agriculture and costs of adaptation', *Food Policy Report*. Washington, DC: International Food Policy Research Institute.

Nelson, G.C. et al. (2010), 'Food security, farming, and climate change to 2050: Scenarios, results, policy options', *IFPRI Issue Brief*. Washington, DC: International Food Policy Research Institute.

Ortiz R. (2011), 'Agrobiodiversity Management for Climate Change', in J.M. Lenné and D. Wood (eds.) *Agrobiodiversity Management for Food Security: A Critical Review*. Wallingford, UK: CABI, pp.189–211.

Pinstrup-Andersen, P. (2009), 'Food security: definition and measurement', *Food Security*, 1(1), pp.5–7.

Pittman, J., V. Wittrock, S. Kulshreshtha, and E. Wheaton (2011), 'Vulnerability to climate change in rural Saskatchewan: Case study of the Rural Municipality of Rudy No. 284', *Journal of Rural Studies*, 27(1), pp.83–94.

Premanandh, J. (2011), 'Factors affecting food security and contribution of modern technologies in food sustainability', *Journal of the Science of Food and Agriculture*, 91(15), pp.2707–14.

Pretty, J., C. Toulmin, and S. Williams (2011), 'Sustainable Intensification in African Agriculture', *International Journal of Agricultural Sustainability*, 9: 5–24.

Raschky, P.A. and H. Weck-Hannemann (2007), 'Charity hazard—A real hazard to natural disaster insurance?', *Environmental Hazards*, 7(4), pp.321–29.

Reddy, V.R., S.K. Singh, and V. Anbumozhi (2016), 'Food Supply Chain Disruption due to Natural Disasters: Entities, Risks, and Strategies for Resilience', *ERIA Discussion Paper Series*, No. DP-2016-18. Jakarta: Economic Research Institute for ASEAN and East Asia (ERIA).

Reddy, V.R. and V. Anbumozhi (2017), 'Managing Stranded Assets and Protecting Food Value Chains from Natural Disasters', *ERIA Discussion Paper Series*, No. DP-2017-01. Jakarta: ERIA.

Rodriguez-Llanes, J.M., S. Ranjan-Dash, A. Mukhopadhyay, and D. Guha-Sapir (2016), 'Flood-Exposure is Associated with Higher Prevalence of Child Undernutrition in Rural Eastern India', *International Journal of Environmental Research and Public Health*, 13(2), pp.210. doi: 10.3390/ijerph13020210.

Rosenzweig, C. et al. (2014), 'Assessing agricultural risks of climate change in the 21st century in a global gridded crop model intercomparison', *Proceedings of the National Academy of Sciences*, 111(9), pp.3268–73.

Rosenzweig, C., A. Iglesias, X.B. Yang, P.R. Epstein, and E. Chivian (2001), 'Climate change and extreme weather events - Implications for food production, plant diseases, and pests', *Global Change and Human Health*, 2(2), pp.90–104.

Shrivastava, P. and R. Kumar (2015), 'Soil salinity: A serious environmental issue and plant growth promoting bacteria as one of the tools for its alleviation', *Saudi Journal of Biological Sciences*, 22(2), pp.123–31.

Silventoinen, K. (2003), 'Determinants of Variation in Adult Body Height', *Journal of Biosocial Science*, 35(2), pp.263–85.

Solomon, S. (2007), *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge, UK and New York, NY: Cambridge University Press.

Sperling, L. (2008), *When Disaster Strikes: A Guide to Assessing Seed System Security*. Cali, Colombia: International Center for Tropical Agriculture.

Sperling, L., H.D. Cooper, and T. Remington (2008), 'Moving Towards More Effective Seed Aid', *The Journal of Development Studies*, 44(4), pp.586–612.

Sthapit, B., S. Padulosi, and B. Mal (2010), 'Role of on-farm/In situ conservation and underutilized crops in the wake of climate change', *Indian Journal of Plant Genetic Resources*, 23(2), pp.145–56.

Thornton, P.K., P.G. Jones, P.J. Ericksen, and A.J. Challinor (2011), 'Agriculture and food systems in sub-Saharan Africa in a 4°C+ world', *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 369(1934), pp.117–36.

Tirado, M.C., R. Clarke, L.A. Jaykus, A. McQuatters-Gollop, and J.M. Frank (2010), 'Climate change and food safety: A review', *Food Research International*, 43(7), pp.1745–65.

Tirado, M.C., D. Hunnes, M.J. Cohen, and A. Lartey (2015), 'Climate change and nutrition in Africa', *Journal of Hunger and Environmental Nutrition*, 10(1), pp.22–46.

Toya, H. and M. Skidmore (2015), 'Information/communication technology and natural disaster vulnerability', *Economics Letters,* 137, pp.143–45.

United Nations Educational, Scientific and Cultural Organization (2010), *Guidebook for planning education in emergencies and reconstruction*. Paris: UNESCO International Institute for Educational Planning. http://unesdoc.unesco.org/images/0019/001902/190223e.pdf (accessed 10 July 2017).

UNICEF (2011), Asia-Pacific. Philippines. https://www.unicef.org/hac2011/files/HAC2011_4pager_Philippines.pdf (accessed 10 July 2017).

UNISDR (2009), *2009 UNISDR Terminology on Disaster Risk Reduction*. http://www.unisdr.org/files/7817_UNISDRTerminologyEnglish.pdf (accessed 10 July 2017).

UNISDR (2015), *The Pocket GAR 2015. Making Development Sustainable: The Future of Disaster Risk Management*. Geneva: UNISDR. http://www.preventionweb.net/english/hyogo/gar/2015/en/home/GAR_pocket/Pocket%20GAR_3.html (accessed 10 July 2017).

Uy, N., Y. Takeuchi, and R. Shaw (2011), 'Local adaptation for livelihood resilience in Albay, Philippines', *Environmental Hazards,* 10(2), pp.139–53.

Verchot, L.V. et al. (2007), 'Climate change: linking adaptation and mitigation through agroforestry', *Mitigation and Adaptation Strategies for Global Change*, 12(5), pp.901–18.

Vernooy, R., B. Sthapit, G. Otieno, P. Shrestha, and A. Gupta (2017), 'The roles of community seed banks in climate change adaption', *Development in Practice*, 27(3), pp.316–27.

Webster, P.J. (2008), 'Myanmar's deadly daffodil', *Nature Geoscience*, 1(8), pp.488–90.

WFP (2015), Capacity Development in Support of the Strategic Grain Reserve in Afghanistan. http://www.wfp.org/operations/200635-capacity-development-support-strategic-grain-reserve-afghanistan (accessed 10 July 2017).

Wheeler, T. and J. von Braun (2013), 'Climate Change Impacts on Global Food Security', *Science*, 341(6145), pp.508–13.

Willenbockel, D. (2011), 'Exploring Food Price Scenarios Towards 2030 with a Global Multi-Region Model', *Oxfam Policy and Practice: Agriculture, Food and Land*, 11(2), pp.19–62.

World Bank (2014), Disaster Risk Management, East Asia and Pacific; 2014:1. Washington, DC: World Bank http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2015/04/23/090224b082e00a32/1_0/Rendered/PDF/Philippines0000own0Option00CAT0DDO0.pdf (accessed 10 July 2017).

Ziska, L.H. and K. George (2004), 'Rising carbon dioxide and invasive, noxious plants: potential threats and consequences', *World Resource Review*, 16(4), pp.427–47.

Zvereva, E.L. and M.V. Kozlov (2006), 'Consequences of simultaneous elevation of carbon dioxide and temperature for plant–herbivore interactions: a meta analysis', *Global Change Biology*, 12(1), pp.27–41.