4 Policy, governance and institutions for reducing and managing losses and damages

This chapter examines the role of policy, governance and institutions in reducing and managing current and future risks of losses and damages from climate change. It first examines approaches to decision making under uncertainty. This is followed by a discussion of approaches to address the components of climate risks (hazards, exposure and vulnerability) before exploring the role of institutions, governance and norms. The final section focuses on the implications of sea-level rise on policy priorities and decision-making processes in Small Island Developing States.

In Brief

Policy, governance and institutions can help address the risks of losses and damages and their underlying drivers in a context of uncertainty

Climate variability and change are radically altering the conditions that societies and ecosystems need to thrive – a trend that will become more prevalent in the future. These changes are overlaid on demographic, economic, technological, political and social changes. Decision makers at all levels therefore must determine which risks to address, how, to what extent and when.

Many different types of uncertainties affect understanding of future climate hazards, exposure and vulnerability. Some cannot be described in terms of probabilities of the range of outcomes. Indeed, sometimes the full range of outcomes may not even be known. This level of uncertainty demands a shift in the nature of decision making. Traditional "predict then act" approaches must give way to decision-making models that make policy and investment choices more robust under a range of potential futures. Science must be complemented by an understanding of and engagement with diverse socio-economic contexts for decisions. Such a process requires effective partnerships that facilitate collaboration across policy and science communities and are inclusive to different types of knowledge, including local and Indigenous knowledge. Finally, they must be considered legitimate by the stakeholders involved.

The intensity and frequency of climate hazards will grow with continuing warming of the climate system. Approaches to reduce and manage these risks must include a focus on the three components of climate risk identified by the Intergovernmental Panel on Climate Change, namely hazards, exposure and vulnerability, as well as their drivers and interactions:

- ***Hazards:*** Limiting the severity of climate hazards requires rapid and deep reductions in global greenhouse gas (GHG) emissions and the protection and enhancement of natural sinks. Cumulative emissions of carbon dioxide need to be capped at a level consistent with efforts to limit temperature increase to 1.5°C. How these challenging goals are approached will have critically important implications for sustainable development and well-being outcomes, as well as implications for the other two components of climate risk (exposure and vulnerability).
- ***Exposure***: Exposure is dynamic, influenced by history; geography; economic, social and institutional context; and individual choices. Climate change itself will affect exposures as the location, frequency and intensity of hazards shift. Policy approaches include regulation (e.g. land use) and standards; pricing mechanisms (e.g. insurance cover) and early warning systems. While direct exposure of people to some hazards may decline with economic development, losses and damages related to livelihoods and assets may increase. Development in high-risk areas and poorly governed urbanisation can significantly increase exposures.
- ***Vulnerability***: The vulnerability of livelihoods, lives and assets is complex. It depends on individual, household, community and societal-level assets, capabilities, institutions (e.g. markets, political and justice system), policies and practices that determine how people and organisations can prepare for and respond to climate hazards. Moreover, practices, infrastructures and ecosystems that may once have been resilient to hazards may no longer be so; climate change will also create novel hazards. At an individual or household level, particularly important capacities are: i) economic (e.g. income diversity, savings, access to social protection and insurance); ii) institutional (e.g. access to, and awareness of, resources that can inform and

facilitate proactive and protective efforts); and iii) political (e.g. access to and active participation in decision-making processes).

The institutions in place will guide efforts to reduce and manage risks. Institutional structures shape the political context for decision making. They empower some interests, while reducing the influence of others. They also influence how risks are perceived, valued, prioritised and addressed. The political process can also change the relevant institutional structures. Approaches to climate risk therefore are inevitably political and a reflection of the diverse values and interests of stakeholders.

Risk governance focuses on processes and institutions that guide and facilitate the management of risks when decisions are made under uncertainty. This can be through adaptive or iterative approaches, highlighting mechanisms that facilitate continuous monitoring, evaluation and learning. Approaches can also build on the growing experience of countries in strengthening the coherence between their climate and disaster-risk communities.

Norms play an important role in determining the nature and scale of action across all three dimensions of climate risk. Some forms of climate action happen relatively rapidly, such as the response to a specific event or repeated events causing widespread losses and damages. However, institutional inertia, values and vested interests can prevent or delay others.

So-called norm entrepreneurs can contribute to the diffusion of new norms by identifying and promoting the implications of different choices. Young people are playing a vital role in bringing climate change to the attention of the broader public. They are pressuring governments to act, while highlighting the implications of individual consumption and lifestyle choices.

Sea-level rise (SLR) is one of several climate hazards threatening Small Island Developing States (SIDS). The policy response to SLR can be grouped in four categories, each with strengths and weaknesses:

- ***protect***, to reduce losses and damages through hard engineering structures or nature-based solutions
- ***advance***, to prevent the propagation of coastal hazards inland by building new land seawards and upwards
- ***accommodate***, to reduce the vulnerability of people, livelihoods and the built environment
- ***retreat***, to reduce or eliminate exposure by moving people, infrastructures and human activities out of the risk zone.

Policy responses to SLR in SIDS will depend on socio-economic circumstances that may transcend this context, e.g. use of early warning systems, emergency planning and contingency planning. However, given the deep uncertainty about future SLR, SIDS must implement flexible options that can be adjusted over time. They must thus determine which long-term decisions can be postponed until the level of uncertainty decreases. Long-term decisions that cannot be postponed, such as on critical infrastructure investments, must factor in SLR. In so doing, the uncertainty preferences of stakeholders will inform the choices made. Many technical options are available for adapting to even high levels of SLR. However, implementing these at significant scale would be costly and lead to radically different coastal landscapes. This would, in turn, threaten the rich cultural diversity and heritage of SIDS. International support to SIDS in the form of finance, technology and capacity should therefore be a policy priority. In addition, deep and rapid cuts in GHG emissions to limit the scale of hazards are urgently needed.

4.1. Introduction

Climate-related extreme events and slow-onset changes are already having devastating and widespread impacts on lives and livelihoods. This is especially true when these changes occur alongside broader social, economic and political stressors. To illustrate, while East Africa in 2020 had to deal with the COVID-19 pandemic and its associated crisis, it also coped with flooding from one of the wettest rainfall seasons in 40 years. Floods displaced hundreds of thousands of people. They also contributed to the loss of crop and livestock equivalent to 70 000 hectares (ha) and 96 000 animal deaths. Meanwhile, the region suffered through the worst locust outbreak in 25 years (Kassegn and Endris, 2021[1]). These concurrent disasters further exacerbated prevailing food insecurity in the region, threatening development gains. The Philippines was also hit by concurrent disasters in 2020. During the COVID-19 pandemic, 22 tropical cyclones hit the country, including the strongest ever recorded to have made landfall (Tropical Cyclone Goni). The cyclones caused widespread destruction, leaving thousands homeless (Rocha et al., 2021[2]). The intensity and frequency of climate hazards will grow with continuing warming of the climate system (IPCC, 2021[3]).

Decision makers at all levels are faced with climate variability interacting with current and projected future levels of climate change. As such, they must determine which risks to address, how, to what extent and when to act. At the household or community level, adaptation to weather and climate hazards may involve adjustments to, or a shift in, livelihood choices. This can entail a change in crops or a shift from farming into other income-generating activities. It may also lead to migration in search of new opportunities, either nationally or internationally, or even displacement (IPCC, 2014[4]). At the national level, damaging weather and climate hazards can reverse development gains. Such a reversal may increase income inequality and the vulnerability of already marginalised segments of society (World Bank, 2021[5]). Hazards directly affecting one country, segment of society or sector may spread to other parts of society. In some cases, hazards may cross local, regional or even national borders, as illustrated in Box 4.1.

Chapter 4 highlights approaches to reduce and manage the risks of losses and damages from climate change. The chapter focuses on the role of policy, governance and institutions. The role of finance and technology are covered in Chapters 5 and 6, respectively. The remainder of this chapter is structured in four sections. Section 4.2 examines approaches to decision making under uncertainty. Section 4.3 discusses approaches to address the components of climate risks (hazards, exposure and vulnerability). Section 4.4 explores the role of institutions, governance and norms. Section 4.5 discusses the implications of sea-level rise (SLR) on policy priorities and decision-making processes in Small Island Developing States (SIDS).

4.2. Decision making under uncertainty

Chapter 3 illustrated the currently serious and potentially devastating future impacts of climate change. These impacts become more likely if action to reduce and manage the risks is not commensurate with the goal of the Paris Agreement to limit temperature increase to 1.5°C. Following 10 000 years of a relatively stable climate, the Earth is now moving into a climatic regime that is rapidly changing (IPCC, 2021[3]; Marshall and Plumb, 2008[6]).

Box 4.1. Globally networked climate risks

The systemic, cross-border nature of many climate risks can be illustrated by their disruptive impacts on agricultural production processes and food security. Modern food systems are both dynamic and complex. They are comprised of formal and informal sectors across product value chains, which may involve international trade. Over 2008-18, the impact of hydrological, meteorological and geological disasters[1] on the agriculture sector[2] in Least Developed Countries (LDCs) and Lower-Middle Income Countries (LMICs) totalled USD 108 billion in damaged or lost crop and livestock production. Across all income groups, this amounted to USD 280 billion or 4% of potential crop and livestock production (FAO, 2021[7]). Such disruptions can fundamentally alter livelihoods and food security given the high dependency of many developing countries on agricultural income (FAO, 2021[7]; Naqvi, Gaupp and Hochrainer-Stigler, 2020[8]).

Production disruptions can also disrupt markets, especially when affecting one or more highly fertile agricultural regions known as "breadbasket" regions (UNDRR, 2019[9]). Around 60% of global grain production occurs in five regional breadbaskets: The People's Republic of China (hereafter "China"), the United States, India, Brazil and Argentina, and in a few regions within those countries. Only four grains account for almost half of the calories of the average global diet (Woetzel et al., 2020[10]).[3] This concentration of production, often in the form of monocultures, delivers economies of scale. However, it is vulnerable to pest infestation, localised extreme weather events and slow-onset changes. Such changes include temperature increases and desertification that can affect a considerable portion of global production (Woetzel et al., 2020[10]). Connections between distant weather phenomena, e.g. the relationship between the El Niño/Southern Oscillation and regional climate extremes such as Indian heatwaves, also increase the risk of simultaneous crop failure across regions (Gaupp et al., 2019[11]).

The unusually intense 2010 heatwave in the Russian Federation (hereafter "Russia") reduced the grain harvest by around a third. This contributed to an initial dramatic increase in international grain prices (up by over 60% between June and August 2010). In mid-August 2020, in response to concerns about the impact on domestic food security, the Russian government imposed an export ban on grain. The ban, which stayed in place until July 2011, further increased international grain prices (Challinor et al., 2018[12]). During the same period, the breadbasket region of Pakistan was affected by devastating floods that displaced over 20 million people, some for months (Naqvi, Gaupp and Hochrainer-Stigler, 2020[8]). The two events were connected meteorologically (Lau and Kim, 2012[13]; Trenberth and Fasullo, 2012[14]) Combined with other extreme weather events that year, they contributed to the price of wheat more than doubling (Challinor et al., 2018[12]).

The risk of such "Multiple Breadbasket Failures" is projected to increase with climate change for wheat, maize and soybean crops and decrease for rice (Gaupp et al., 2019[11]). International mechanisms are in place to reduce and manage these risks. These include monitoring and early warning of crop failures and co-ordination of food distribution based on humanitarian need in the event of shortages (Janetos et al., 2017[15]). Further policy proposals put forward include formalisation of grain reserve arrangements and binding agreements between a small set of grain traders (Headey and Fan, 2008[16]).

Notes:

1. Hydrological, meteorological and geological disasters (and the associated losses in LDCs and LMICs) include i) drought (34%); ii) floods (19%); iii) storms (18%); iv) earthquakes, landslides and mass movements (13%); v) crop and livestock pests, diseases and infestations (9%); vi) extreme temperatures (6%); and vii) wildfires (1%).

2. Including crops, livestock, forestry, fisheries and aquaculture.

3. The main breadbasket regions differ across crops (Woetzel et al., 2020[10]): ***For wheat***: China, European Union, India, Russia and the United States; ***for corn***: Argentina, Brazil, China, European Union and the United States; ***for soy***: Argentina, Brazil, China, India and the United States; ***for rice***: Bangladesh, China, India, Indonesia and Viet Nam.

4.2.1 The changing nature of risk and uncertainty

Areas that historically have had to manage floods may in the future face challenges associated with droughts for which there is little management experience. In high mountain regions, for example, snowmelt and glacier retreat are contributing to a short-term increase in water availability. This coincides with other risks, including glacier lake outburst floods. Following an increase in water supply in the short-term, water supply will start to diminish (Hock et al., 2019[17]). In the Himalayan region, uncertainties in climatic projections and glacier dynamics could have major implications for more than a billion people in the wider region that depend on this Asian "water tower" (Scott et al., 2019[18]; Mishra, 2015[19]).

Areas at risk of wildfires may see the frequency and magnitude of these events increase to unprecedented levels (Goss et al., 2020[20]). Slow-onset changes such as SLR will increasingly threaten livelihoods and lifestyles of coastal and island communities. These include threats to traditional belief and cultural systems (McNamara, Westoby and Chandra, 2021[21]). Crossing tipping points in the climate system could trigger major transformations to the climate system and significant disruptions to economies and societies, both regionally and globally. Thresholds at which such tipping points would be triggered are uncertain. However, some may already be close or even exceeded (Lenton et al., 2019[22]). This highlights the novelty of potential challenges for policy makers in identifying and implementing approaches to reduce and manage the risks of losses and damages from climate change.

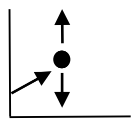
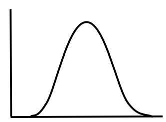
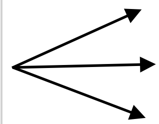
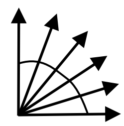
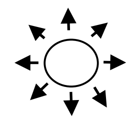
Different types of uncertainties limit the applicability of historical data for understanding future climate hazards. As discussed in Chapter 2, this includes uncertainties stemming from i) future emissions linked to different demographic and socio-economic pathways; ii) uncertainty in the response of the global climate system to different levels of emissions and aerosols; and iii) the natural variability of the climate system (Zheng, Zhao and Oleson, 2021[23]). Additionally, there are uncertainties in the other components of climate risk (i.e. exposure and vulnerability), such as the sensitivity to a given change in climate of people, assets and activities. These uncertainties have called into question the traditional "predict then act" approach. Instead, given the high costs of inaction or delayed action, policy processes and decisions can usefully be guided by robust and flexible policy choices that make them suitable to a range of potential future climates (Vincent and Conway, 2021[24]).

A focus on robustness and flexibility in decision making needs to consider the values and perspectives of actors in the process (Marchau et al., 2019[25]). One key aspect is the level of uncertainty in the system about which a decision is needed (see also Chapter 2). If the extreme ends of the decision-making spectrum are defined as full certainty or total ignorance, four intermediate levels of uncertainty include (Marchau et al., 2019[25]) (see also Figure 4.1)

- ***Level 1***: There is not full certainty but decision makers generally do not consider it necessary to measure the degrees of uncertainty. This can apply to short-term decisions for a well-defined system where historical data are seen as a good indicator of the future.
- ***Level 2***: The parameters in the model used to describe the real-world system are used to estimate the probability distribution for a few alternative futures. Related policy processes can be informed by expected outcomes and levels of acceptable risk.
- ***Level 3***: There is a limited set of plausible futures, but the level of uncertainty is such that probabilities cannot be assigned to them. Instead, scenario analysis can point to policies that will produce more favourable outcomes. The "best" policy will produce the most favourable outcomes (a political/social choice) across the different scenarios.
- ***Level 4***: This level of deep uncertainty can apply to two situations. In the first, there are many plausible futures due, for example, to lack of knowledge or data about the functional relationships. In the second, the future is not even qualitatively known due, for example, to unpredictable high-impact events. It can either be difficult (first case) or impossible (second case) to describe

interactions among the variables, determine the probability distribution for different outcomes or even value the desirability of alternative outcomes.

Figure 4.1. Sample characteristics of different levels of uncertainty

	Full certainty	Level 1	Level 2	Level 3	Level 4 (deep) uncertainty		Total ignorance
					Level 4a	Level 4b	
Context (x)		A clear enough future 	Alternate futures (with probabilities) 	A few plausible futures 	Many plausible futures 	Unknown future 	
System model (R)		A single (deterministic) system model	A single (stochastic) system model	A few alternative system models	Many alternative system models	Unknown system model; know we don't know	
System outcomes (O)		A point estimate for each outcome	A confidence interval for each outcome	A limited range of outcomes	A wide range of outcomes	Unknown outcomes; know we don't know	
Weights (W)		A single set of weights	Several sets of weights, with a probability attached to each set	A limited range of weights	A wide range of weights	Unknown weights; know we don't know	

Note: This table assumes four primary locations of uncertainty: external forces (X); the structure of the system mode and its parameters (R); the system outcomes (O); the relative importance of specific outcomes placed by the actors in the policy domain (W).
Source: Adjusted from (Walker, Lempert and Kwakkel, 2013[26]).

In terms of climate change, different hazards across different timescales will have different levels of uncertainty associated with them. For example, SLR rise is a slow-onset change that occurs over decades. Conversely, extreme events such as heavy precipitation can occur over hours or days. The uncertainty of these different types of hazards, and thus how to address them, varies widely. In the context of SLR over the coming decade, it may be sufficient to consider a small range of possible futures. These would revolve around a central estimate determined by the rate of thermal expansion of the upper sea surface and the additional water from glacier and ice-sheet melt. On longer timescales, there is arguably a limited number of different plausible futures. However, it is difficult to place credible probabilities on the occurrence of each possible outcome.

For extreme events, the occurrence of some can be predicted on a timescale of several days, such as the heavy precipitation event in Pakistan in 2010 (Webster, Toma and Kim, 2011[27]). On longer timescales, dynamic aspects of climate change, such as changes in average precipitation, are highly uncertain (Shepherd, 2014[28]). The potential crossing of tipping points in the climate system is at the high end of the uncertainty spectrum. It is not possible to attach probabilities to the activation of particular tipping points. Moreover, there is a wide range of potential outcomes from crossing a given tipping point. Some future states of the climate are unknown or very imperfectly known.

4.2.3 The rise in decision-driven approaches to uncertainty

The past few decades have seen a rise in decision-driven approaches that recognise the need for decisions to both reduce the risks and to strengthen resilience in the face of inherent uncertainties. Such decision-driven approaches typically rely on institutional structures that facilitate an iterative approach informed by learning and recognise the interconnectedness, complexity, feedbacks and thresholds across different systems and impacts. Box 4.2 briefly summarises three approaches to decision making under uncertainty that have received prominent attention in the academic literature and increasingly inform policy processes. Discussion on further approaches and additional details are available in Marchau et al. (2019[25]). Box 4.3 illustrates how different approaches combined can guide decision-making processes in the agricultural sector in Uganda, where future levels of precipitation are uncertain.

Box 4.2. Examples of approaches on decision making under uncertainty

Robust Decision Making (RDM)

RDM approaches provide a set of concepts, processes and tools that use computation to yield better decisions under conditions of uncertainty (Lempert, 2019[29]). RDM approaches combine decision analysis, scenarios and modelling to stress test different policy approaches against a wide range of plausible future pathways, rather than making predictions. Analysis of the model runs then help decision makers identify key features that distinguish those futures in which their plans meet or miss set policy goals (Lempert, 2019[29]). In developing countries, data requirements and resource constraints among others limit the uptake of RDM approaches (Bhave et al., 2016[30]). This results in research exploring how simplified modelling approaches can provide decision support, e.g. in the context of the Lake Tana basin in Ethiopia (Shortridge, Guikema and Zaitchik, 2016[31]).

Dynamic Adaptive Policy Pathways (DAPP)

The DAPP approach recognises the multitude of uncertainties that decision makers face (i.e. climate change and broader socio-economic factors). It calls on planners to establish a framework for action informed by a strategic vision of the future and guided by short-term, flexible actions that can be adjusted to reflect changing circumstances (Haasnoot et al., 2013[32]). In this way, the DAPP approach provides a decision space that helps overcomes policy paralysis in the context of uncertainty. Biophysical, cultural, socio-economic, and political-institutional dimensions determine why, how, when and who acts on climate. Decisions today may open up some options while foreclosing others; changes in the biophysical and socio-economic systems also determine the range of future available options (Haasnoot et al., 2020[33]). The DAPP approach has informed policy that focuses on water risk management in delta areas, such as in the Netherlands (Government of the Netherlands, 2020[34]), Bangladesh (Government of Bangladesh, 2018[35]), in the Murray-Darling Basin in Australia (Murray-Darling Basin Authority, n.d.[36]) and in the context of the Thames Barrier in the United Kingdom (UK Government, 2021[37]).

Storylines approach

The storylines approach aims to identify plausible climatic and socio-economic factors that drive risks to assess the impact of particular actions in a context where future changes in the climate are uncertain (Shepherd, 2019[38]). The approach may be informed by particular types of (historical or plausible) events with high societal impacts, or particularly dangerous physical pathways of the climate system (e.g. tipping points) (Shepherd et al., 2018[39]). The emphasis on plausibility and the event-based nature of the storyline approach makes it well suited for a variety of purposes. It can improve risk awareness; strengthen decision making; explore the boundaries of plausibility of certain climate projections; provide a physical basis for understanding the different components of uncertainty; and link physical climate information with human aspects of climate change (Shepherd et al., 2018[39]).

The technical complexity of some decision-driven approaches limits their applicability to developing countries. In some developing countries, for example, data availability may be sparse or unreliable and computing and technical capacities inadequate (Shortridge, Guikema and Zaitchik, 2016[31]). In such contexts, simplified analytical processes have been applied. For example, hydrologic models are replaced by simple relationships or assumptions about how climate conditions impact streamflow. They may also focus on individual variables rather than the broader systems (Shortridge, Guikema and Zaitchik, 2016[31]). Such simplifications require a good understanding of potential implications on outcomes. Alternatively, policy choices can be tested against explicit statements of causal relationships, or theories of causation, to guide reasoning over choices and outcomes (Popper, 2019[40]).

Uncertainty and long-lived infrastructure

This explicit treatment of uncertainty is particularly valuable in the context of large investments in long-lived infrastructure such as energy, transport, coastal protection and water management systems (Shortridge, Guikema and Zaitchik, 2016[31]). Failure to treat uncertainty risks locking in long-lived investments that may exacerbate the exposure of people and assets to future climate risks. A focus on uncertainty instead contributes to approaches that perform well under a set of different future conditions. This can then be more politically palatable than large and potentially irreversible decisions (Bhave et al., 2016[30]).

The Thames Barrier illustrates the treatment of uncertainty. The Barrier was designed to be adaptable to different SLR rates and change affecting the estuary up to around 2070. Different options have been identified for improving or replacing the Barrier. However, given the adaptive nature of the approach, a final decision will not likely be needed until around 2040 (UK Government, 2021[37]).

Where long-lived infrastructure is in place, and the focus is largely on maintenance and modification rather than construction, the resilience of the system to different climate futures should be assessed. This process may guide efforts to retrofit infrastructure or add redundancy. In this way, when extreme weather events bring down one component of the system, other components can take over (OECD, 2018[41]; OECD, 2020[42]). While adding redundancy to systems will increase initial costs, this can be seen as a form of insurance against extreme events.

Reconciling long-term investments with election cycles

The benefits of investments to address these risks of losses and damages may only materialise over time. This can pose a challenge for elected officials (Evans, Rowell and Semazzi, 2020[43]). Research has shown that voters are more likely to reward an incumbent presidential party for delivering disaster relief spending than for investing in disaster preparedness (Healy and Malhotra, 2009[44]). Most decision makers also respond to budgetary planning cycles that often do not favour a focus on long-term goals (Evans, Rowell and Semazzi, 2020[43]). Climate hazards must therefore be clearly communicated for advances in science to guide decision making (Jack et al., 2021[45]) (see Chapter 2).

Co-production approaches where producers and users of the information work together to translate science into actionable information can also guide policy processes (Vincent et al., 2021[46]). This can also facilitate a focus on local or sector perspectives (Cornforth, Petty and Walker, 2021[47]). Agreed and transparent processes for addressing the preferences and values of current and future generations are also important (Lawrence and Haasnoot, 2017[48]) (see Section 4.4.2). Unprecedented extreme events in 2021, such as the record temperatures over British Columbia, Canada, underline that damaging climate hazards are no longer for the distant future.

Box 4.3. Uncertainty and the use of decision-driven approaches in East Africa

Over Africa, and especially East Africa, future climate projections of precipitation are particularly uncertain. There is limited understanding of the physical processes that control the amount of rainfall during the rainy seasons. Recent drying in East Africa has caused many areas to suffer from droughts and food shortages. These impacts contrast with projections from most climate models of a wetter future. The divergence between projections and reality is referred to as the "East African climate paradox" (Wainwright et al., 2019[49]). The uncertainty in the region affects multiple aspects of society, including food security, water availability for crops and livestock, public health and infrastructure; impacts that are playing out against a broader set of socio-economic risks.

As part of the Future Climate for Africa (FCFA) programme, the HyCRISTAL (Integrating Hydro-Climate Science into Policy Decisions for Climate-Resilient Infrastructure and Livelihoods in East Africa) project has developed three future ***climate storylines*** for East Africa. These capture the diversity in climate projections for the region (Burgin et al., 2019[50]):

- ***Future 1***: Much wetter, large increase in extreme rainfall and hotter.
- ***Future 2***: Increase in extreme rainfall and hotter.
- ***Future 3***: Much hotter and drier with more erratic rainy seasons.

The three climate futures have different implications for food security and livelihoods. The storyline approach to dealing with uncertainty (defined in Box 4.2), can be used to analyse quantitatively key variables affecting yields of key crops. In the context of sweet potato farming in Uganda, for example, this analysis includes total precipitation over the growing season; number of days with temperature between 17°C and 30°C; number of days with temperature above 30°C; monthly average precipitation; and monthly average maximum temperature. By drawing on daily weather data, quantitative climate storylines can be developed, representing the three climate futures and using values as described by Burgin, Rowell and Marsham (2020[51]) (see Table 4.1). These quantitative climate storylines can be inputted to a ***crop network model*** using observed weather data as the baseline.

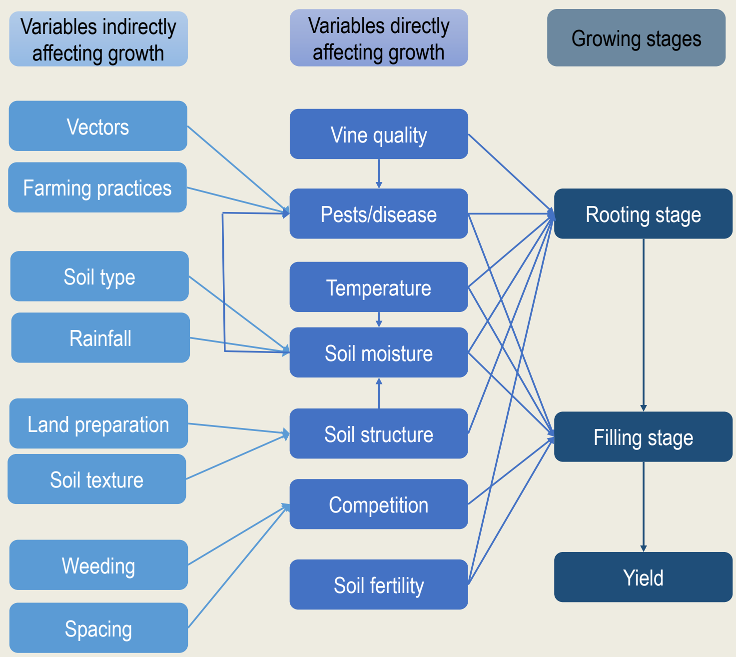
Table 4.1. Quantitative interpretation of the three climate future storylines for East Africa

	Climate future 1	Climate future 2	Climate future 3
Change in annual temperature (°C)	+ 2	+ 2.5	+ 3.1
Percentage change in precipitation DJFM	+ 17.5	+6.0	+4.0
Percentage change in precipitation AM	+ 27.5	+ 12.0	- 4.0
Percentage change in precipitation JJA	+ 21.0	+ 1.0	- 2.0
Percentage change in precipitation SON	+23.0	+ 2.5	- 8.0

Note*:* Temperature change is presented as absolute change in degrees Celsius. Precipitation is presented as a percentage change for four distinct periods of the year: December, January, February, March (DJFM); April, May (AM); June, July, August (JJA); September, October, November (SON).
Source*:* (Burgin et al., 2019[50]).

To simulate the effect of the climate storylines, a model can be developed based on a ***causal inference network.*** This brings together information from different sources, including data, models and expert knowledge to support decision making (Pearl and Mackenzie, 2018[52]). The network summarised in Figure 4.2 sheds light on the links between climatic and non-climatic variables, and how they interact to influence sweet potato crops in Uganda. This information can inform efforts to explore the implications of the different climate storylines in the medium to long term, including for food security, health and nutrition, and the wider economy. As such, causal networks enable relevant climate information to be made meaningful at the local scale. This highlights the benefits of close partnership and dialogue between researchers and local stakeholder communities to improve decision making and outcomes.

Figure 4.2. Causal network of key drivers of sweet potato growth



The causal network can inform quantitative analysis focused on a subset of the network for which data and knowledge are available (e.g. temperature, rainfall or the likelihood of pest infestation). To quantify the interactions between the variables, the network can be parameterised as a ***Bayesian Belief Network*** (BBN) [see (Fenton and Neil, 2012[53])]. Within a BBN, the possible states of each node are defined. For example, the amount of rainfall could be categorised as "high", "medium" or "low", with ranges defined for these categories. Conditional probability tables are then produced for each node. These describe the probability of each state of the node occurring, conditional on the values of the parent node. For example, the probability of high soil water content at planting depends on the amount of rainfall in the two weeks prior to planting. The causal structure of the network allows these key interactions to be identified.

The analysis has to be taken a step further to understand how changes to crop yields and prices impact livelihoods. Considerations include the local context; the range of crops grown and their likely response to different climate change scenarios; the relative importance of different crops to different wealth groups within the community; and the various coping strategies these groups can access. The ***Household Economy Approach*** (HEA), widely used by African governments for vulnerability assessments, draws on detailed social and economic data to simulate the impact of yield and price changes on household income and food security (Seaman et al., 2014[54]; Acidri et al., 2018[55]). The ***Integrated Database and Applications for Policymakers*** platform enables storage and analysis of HEA data and provides a platform to link to different models driving impact scenarios (Cornforth, Clegg and Petty, 2021[56]).

A decision-centric framework based on the principles of ***Dynamic Adaptive Policy Pathways*** (DAPP) (see Box 4.2) can be used to select appropriate policy action today in the face of an uncertain future. Here, the policy objective is to prevent an increase in crop failure under the three alternative climate storylines, informed by key intervention points. While this process may be informed by different technical approaches, reliance on local knowledge and practice is central.

When the methodology described above is applied to assess the impact of climate change on sweet potato farming in Uganda it shows that projected crop yields are less vulnerable to rainfall extremes than previously thought. Efforts to control pest infestations (e.g. the sweet potato weevil, *Cylas formicarius*) could offset even the most severe anticipated climate impact. This has implications for the relative emphasis placed on different crops in a changing climate. Unlike engineering or infrastructure options, changes to agricultural policy interventions will likely be gradual responses to changes in the climate. Mechanisms are needed that enable farmers to better respond to climate stresses through, for example, investment in small-scale irrigation and provision of clean planting materials. At the same time, investment should continue in agricultural research into improved varieties of sweet potato (see other policy options summarised in Table 4.2).

Table 4.2. Options for policy action and intervention for sweet potato farming in Uganda

	Policy action and interventions
Local-level interventions	• Improve pest management by provision of clean (weevil-free) planting material. • Reduce water stress: small-scale irrigation, improved system for capture and storage of rainwater (rainwater harvesting), and use of cover crops to improve soil water retention. • Introduce drought-resistant crop varieties or switch crops entirely – such as intensifying sweet potato production in place of maize.
National-level policy actions and interventions	• Provide budgets for large-scale pest reduction/eradication. • Improve farmer access to new scientific knowledge and enhanced technical support to optimise planting dates and take more timely decisions to build their resilience. • Invest in basic agricultural infrastructure and services, including allocating ongoing budget to support agricultural extension – both training and maintaining. • Enhance the agro-meteorological observation network to support localised climate information services for agriculture to provide a full range of advice regarding climate and its impacts on crops. • Long-term investment in agricultural research, developing new crop varieties that will be better suited to the range of climate futures. • Investment in tracking long-term changes at a household level through decentralising data collection and building local capacity to conduct Household Economy Assessments.
Global-level policy actions	• Reduce global emissions of greenhouse gases. • Provide finance, support the development of technical expertise and invest in national-scale networks to provide quantitative information on the social and economic impacts of agricultural infrastructure investments, governance change, local financing arrangements against the backdrop of climate and environmental change. These require global-level commitments and often levels of investment beyond the capability of national governments in developing countries.

4.3. Addressing the urgent challenge of losses and damages

Reducing and managing the risks of losses and damages from climate change requires enhanced focus on the three components of climate risks (i.e. hazard, exposure and vulnerability), the drivers that bring about changes in those components and their interactions, as conceptualised in the Intergovernmental Panel on Climate Change (IPCC) (see Chapter 1). Hazards are the result of the heating effect of previous greenhouse gas (GHG) emissions with complicated influences on regional weather and climate from other pollutants, such as aerosols. Levels of exposure and vulnerability at local, national and regional levels to these different hazards have been shaped by historical, geographical, social, political, cultural and economic circumstances.

However, countries cannot reduce or manage to all risks, whether due to financial, technical or physical constraints resulting in losses and damages (see Chapter 1, Box 1.2). In the face of often devastating or repeated losses and damages, the importance of complementing climate change adaptation with efforts to reduce disaster risks and otherwise limit the creation of hazards and strengthen the resilience of systems has risen on the international agenda (OECD, 2020[57]). A focus on the components of climate risks can be explicit or implicit. An explicit focus, for example, could examine land-use management, agricultural practices and infrastructure standards. An implicit focus might look at livelihoods development, social protection or basic health. Whether explicit or implicit, such a focus may occur *ex ante* or *ex post*. An *ex ante* focus could pro-actively reduce the creation of the hazard or to lessen exposure and vulnerability. An *ex post* focus could lessen the impact of hazards, including emergency relief and longer-term reconstruction to reduce future vulnerability.

Given the pace and extent of climate change, rapid and in some cases transformative changes (Fedele et al., 2019[58]) may be needed, rather than incremental improvements in resilience. Such a transformative approach could aim at fundamentally altering the relationships between the hazard and one or both of the other two components of climate risk. For example, an incremental change – often through technical improvements – could achieve a marginal reduction in exposures or vulnerability. Conversely, in a more transformative response to exposure, a community could be relocated in response to SLR and coastal flood risks (see Section 4.3.3 for other examples). Similarly, large-scale policy interventions targeting pre-existing health or financial inequalities could transform the geography of vulnerability to certain hazards. Given the scale, novelty and frequency of climate-related hazards now and increasingly in future decades, societies will either have to deliberately transform themselves or face unplanned transformation into potentially unfavourable states (Levin et al., 2021[59]).

This section examines the role of policy in addressing each of the three components of climate risk, while Section 4.4 examines the role of policy, governance systems and institutions. The role of finance in reducing and managing risks is discussed in Chapter 5.

4.3.1. Mitigating the climate hazards

The IPCC risk framework emphasises the mitigation of GHG emissions as a central priority to reduce the magnitude of climate hazards. Success in limiting the average global temperature increase is determined by the ability of the international community to achieve timely "net-zero global anthropogenic carbon dioxide (CO_2) emissions and declining net non-CO_2 radiative forcing" (IPCC, 2018[60]). Hence, Article 4 of the Paris Agreement calls for Parties to rapidly reduce emissions "to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century" (UNFCCC, 2015[61]).

In the case of CO_2, such a balance can be achieved through natural "carbon sinks" such as forests and peatland. However, they do not guarantee permanent sequestration of CO_2 in the same way as technologies such as carbon capture and storage. Still, they can simultaneously offer other ecosystem benefits, such as reduced vulnerability of downstream river catchments to flood hazards. Action to reduce CO_2 emissions will also reduce emissions of other pollutants (e.g. methane, nitrous oxide and black carbon) that contribute to climate change. At the same time, additional non-CO_2 mitigation measures (e.g. in agriculture and waste treatment) could help reduce the pace of climate change and limit global average surface temperatures in the short term. These measures could also provide immediate air quality benefits (IPCC, 2018[60]; Harmsen et al., 2019[62]).

Net-zero commitments

Net-zero commitments vary in terms of the definition used; the timeframe; target; status; scope of GHG emissions and sectors covered; as well as governance mechanisms and institutional arrangements adopted. Moreover, many details are currently unclear, especially how countries plan to meet their net-zero commitments, the relative focus on emissions reductions, removals or use of international carbon markets; and the underlying assumptions (e.g. future technologies for direct air capture and land availability) (Jeudy-Hugo, Lo Re and Falduto, 2021[63]).

A survey published in March 2020 found that 124 countries, representing 61% of global emissions, had net-zero commitments in place. Around 40% of these commitments focus on CO_2 emissions, a slightly larger share target all greenhouse gases, with the remaining 14% not specifying which gases are covered (Black et al., 2021[64]). The survey also noted that national commitments are increasingly complemented by commitments put forward by subnational governments and the private sector. Over one-fifth of public companies surveyed in 2020 have net-zero commitments (Black et al., 2021[64]). Of these, only around 20% meet the robustness criteria defined or informed by the UN Race to Zero Campaign (pledge, plan, proceed, publish).

National circumstances will determine countries' net-zero pathways. These circumstances include levels of economic development, resource endowments, and the drivers of emissions by sector or activity. Equally important is the extent to which their emissions reduction pathways focus on reducing demand, as well as decarbonisation of key technologies and infrastructures (OECD, 2017[65]). Some pathways risk not being realised. This includes pathways that exhibit continued growth in CO_2 emissions in the next decade or beyond. They also assume availability and extensive use of carbon dioxide removal (CDR) technologies later in the century. The risk for such pathways is particularly high since most CDR technologies are still at the early stages of development, which contributes to high uncertainties for policy makers.

All sectors will require rapid, far-reaching and unprecedented transitions with deep emissions reductions (IPCC, 2018[60]), but potential for decarbonisation varies. Agriculture and forestry sectors, for example, have more potential for decarbonisation than aviation and heavy industries (Rogelj et al., 2021[66]; OECD, 2017[65]). For the energy sector to achieve net-zero emissions by 2050, two policy shifts are required. First, all new oil, methane gas and coal exploration projects will have to be stopped. Second, gas must be precluded as a "bridge fuel" in the energy transition (IEA, 2021[67]). This sends an important message to policy makers and investors of the inevitable and urgent need to manage the decline of energy based on fossil fuel.

Some of these fossil fuel investments are underpinned by both direct and indirect support. Direct support comes through budgetary aid in financing fossil fuel projects. Meanwhile, fossil fuel subsidies and preferential tax provisions indirectly support fossil fuel production (OECD/IEA, 2021[68]). Support in 2019 for fossil fuel production rose by 30%, primarily recorded in OECD countries (OECD/IEA, 2021[68]). International public finance is also supporting financing for gas expansion in the Global South, which could mean continued operations for several decades (Muttitt et al., 2021[69]). In September 2021, China announced that it will end financing of all overseas coal projects.

Managing trade-offs and synergies with sustainable development

National policies announced or implemented to date fall far short of what is needed to achieve net-zero targets. Policy makers face difficult choices to determine future mitigation pathways. Each choice has implementation challenges, potential synergies and trade-offs with broader sustainable development objectives (IPCC, 2018[60]). The trade-offs, however, are comparatively lower for pathways relying on low-energy demand, low material consumption, and low GHG-intensive food consumption (IPCC, 2018[60]). How policy makers approach these challenging goals will have critically important implications for sustainable development and well-being outcomes, as well as implications for the other two risk components (exposure and vulnerability). As countries seek to recover from the economic aftermath of the COVID-19 pandemic, such pathways also hold greater potential to deliver synergies between climate mitigation and broader sustainable development (or well-being) objectives (Buckle et al., 2020[70]).

The deep transformations required to achieve net-zero globally will be facilitated through fair and inclusive processes for addressing structural change. Such processes must leave no one behind, whether segments of society or across countries (IPCC, 2018[60]). Co-ordinated support in the form of financial or technological know-how will be important for many developing countries. This will allow climate mitigation to be an integral part of development rather than at the expense of it. For example, in the energy sector, developing countries will need to continue to meet the energy needs of growing populations, while reducing emissions. Through international co-operation, the development and implementation of international standards and innovation, countries can pursue these twin objectives in a sustainable manner (IEA, 2021[67]).

Transition strategies that integrate climate mitigation and wider well-being goals will help identify and address trade-offs and enhance synergies between them. This will enhance the benefits and feasibility of mitigation action, making it easier for the population to choose sustainable options (OECD, 2021[71]). At the domestic level, targeted support may still be required for segments of the population directly affected by the transition. These groups may either face loss of employment or higher prices for energy and food (Soergel et al., 2021[72]). Fossil fuel subsidies for production and consumption could be reformed to free up fiscal resources, allowing redistribution of national carbon pricing revenues to these vulnerable groups.

Developed countries carry the primary responsibility to lead the net-zero transition. International climate finance linked to projects that reduce GHG emissions can help accelerate mitigation in developing countries while supporting development. Moreover, targeted finance in large-emitting developing countries can help reduce the risks of losses and damages for all developing countries by lowering the level of hazard. To achieve this outcome, however, emissions must not increase in response to lower hazards, either in the recipient country or elsewhere.

4.3.2. Minimising exposure to weather and climate hazards

Apart from mitigating climate hazards, the IPCC risk framework aims to reduce exposure of lives, livelihoods, economic activities and assets to weather and climate hazards. LDCs, SIDS, and Arctic ecosystems, high mountains and dryland regions are disproportionately exposed to climate variability and change due to their geographic locations and physical characteristics (IPCC, 2018[60]; IPCC, 2019[73]). Exposure is further determined by factors such as demographic change, urbanisation, natural resource management, the availability of livelihoods options and governance arrangements (IPCC, 2012[74]; Duvat et al., 2017[75]). With economic development, people and assets become concentrated in urban centres. As the climate changes, societies might also become exposed to hazards they have not previously faced and to which they might therefore be more vulnerable. For example, climatic changes may extend the range of disease vectors such as mosquitos.

In some countries, increases in exposure may also be correlated with increased vulnerability (see below). This can occur when rapidly growing informal settlements challenge the capacity of local governments both to provide essential services and enforce land-use management regulations (Sudmeier-Rieux et al., 2015[76]). Urban growth may also lead to an expansion of developments into areas that offer a certain lifestyle (e.g. forests, coasts) but also higher exposure to hazards (OECD, 2021[77]).

Climate change itself will alter the intensity, spatial and temporal occurrence of hazards, transcending the range of historic experience in a given location. Such extremes are occurring now, affecting people that may not have considered themselves exposed to such hazards in the past. This was illustrated by the 2021 heatwave over North America. The maximum temperature in Lytton, British Columbia, Canada, was 49.6°C on 29 June, exceeded the previous temperature record by 4.6°C. Similarly, in June 2020, record-breaking temperatures up to 38°C in the Siberian town of Verkhoyansk, caused wide-scale impacts, including wildfires, loss of permafrost and an invasion of pests. Some areas of Siberia exceeded monthly averages by more than 10°C above the 1981-2010 average.

The relative contribution of climate change and other factors in driving exposure varies across contexts and hazards. Both current and future exposure of assets to coastal flooding, for example, are not primarily due to SLR. Rather, rapid urbanisation strains infrastructure and introduces environmental and socio-economic problems (Hinkel et al., 2014[78]; Mason et al., 2020[79]). In comparison, climate change itself is projected to be a stronger determinant of future exposure to heatwaves than demographic change (Jones et al., 2018[80]). Early warning systems (EWS) have played an important role in reducing the exposure of lives (see Box 4.4). However, this does not always reduce vulnerability of livelihoods and assets.

Box 4.4. Bangladesh: Complementing efforts to reduce exposure and vulnerability to hazards

Due to its location, topography and multiple river systems, Bangladesh is exposed to numerous weather hazards, including cyclones, heavy rainfall, floods and drought (Haque et al., 2018[81]; Shakhawat Hossain et al., 2020[82]). Its vulnerability is furthered by high population density and multidimensional poverty. Between 1991 and 2011, it experienced 247 extreme events with an average annual death toll of 824 and financial losses of 1.18% of gross domestic product (GDP) (Nishat et al., 2013[83]). Financial losses went as high as 6% of GDP for some individual events (Haque et al., 2018[81]).

In response, the government has enacted laws, policies and procedures to reduce exposure to such hazards (Haque et al., 2018[81]; Kumar, Lal and Kumar, 2021[84]). This has included a shift in emphasis from disaster relief and recovery to early warning and evacuation, and construction of multi-purpose cyclone shelters. Nature-based solutions, such as planting mangroves and restoring sand dunes, have also lessened the impact of hazards on coastal communities (Rahaman et al., 2020[85]).

In 2018, the government introduced the Bangladesh Delta Plan 2100 that takes an adaptive decision-making approach (see Box 4.2) where policy priorities are adjusted as hazards change. For example, emphasis may shift from improving embankments to building safer ones (Pakulski et al., 2021[86]). This shift in policy has been effective in protecting lives. During Super-cyclone Amphan that hit the Bay of Bengal in May 2020, early warning and evacuation systems led to evacuation of up to 2.5 million people to shelters, limiting the death toll in Bangladesh to 12 (Kumar, Lal and Kumar, 2021[84]; IDMC, 2021[87]).

Nevertheless, Amphan destroyed 150 kilometres of embankments, which led to flooding of infrastructures, agricultural lands and fields that remained inundated for months (IDMC, 2021[87]). Many displaced people could not access evacuation centres and had to shelter in tents or on open embankments (WMO, 2021[88]). While most evacuated people could return home relatively quickly, about 10% were left homeless (UN, 2020[89]; Kumar, Lal and Kumar, 2021[84]). In a survey seven months after the cyclone, respondents said they had reduced their food intake and medical expenses. Nearly 70% had resorted to begging, borrowing or selling household assets (IDMC, 2021[87]).

Amphan is not an isolated case; Cyclone Sidr in 2008, Isla in 2009, and Fani and Bulbul in 2019 all struck the same areas (IDMC, 2021[87]). The impact on livelihoods is expected to worsen as climate change increases. Sea-level rise (SLR) and saline intrusion will gradually contaminate soils and groundwater, adversely affecting agriculture, a main source of livelihood income for the rural population (Khan et al., 2021[90]; Shakhawat Hossain et al., 2020[82]; Clarke et al., 2018[91]). By 2080, 18% of Bangladesh's coastland is projected to be inundated (Khan et al., 2021[90]). Adapting cultivation practices may not be enough (Chen and Mueller, 2018[92]). Extreme floods, cyclones, drought and heat stress could cut yields for rice, wheat and potato by over two-thirds of current levels and in some cases threaten food security (ADB, 2014[93]).

Reduced exposure to hazards must therefore be complemented by reduced vulnerability to the hazards. Sectoral and short- and long-term development policies have focused on this dual approach. In addition, Bangladesh could further protect at-risk populations by strengthening coherence with climate change adaptation (Shamsuddoha et al., 2013[94]; Islam, Chu and Smart, 2020[95]). In 2019, the government initiated a two-year pilot programme to develop a national mechanism on loss and damage. It seeks to i) firmly embed climate change perspectives within policy approaches on disaster risk reduction; ii) address gaps in policy frameworks on climate change adaptation and disaster risk reduction; and iii) design a comprehensive system for a stronger response to losses and damages from climate impacts (Haque et al., 2018[81]).

Following a disaster, decision makers must determine how to respond amid expectations that such events are opportunities for building back or forward better. Experience seems to suggest that the public directly affected by a disaster will often favour policies focused on "building back the same" (Frank, Gesick and Victor, 2021[96]). For people in power, it can be politically difficult to relocate people who have lost everything due to an extreme event. Instead, they are more likely to promise a safe and swift return to previous ways of living. In response to a hurricane, assessments of future risks of similar magnitude at the same location may be sufficiently low to rebuild damaged assets. However, increasing hazards will gradually make this approach less sensible; incentives to reduce future exposure will be urgently needed (Frank, Gesick and Victor, 2021[96]). In other cases, working with nature to reduce and manage climate risks may be an alternative or complementary approach (see Box 4.5).

Approaches to reduce and manage the risks of losses and damages can indirectly contribute to enhanced exposure. Two commonly cited examples illustrate this issue well. First, flood protection measures to reduce vulnerability can indirectly encourage developments on floodplains, increasing exposure. Research from Bangladesh, for example, finds that flood death rates associated with the 2017 flooding were lower in areas with lower protection level (Ferdous et al., 2020[97]). Second, insurance mechanisms play an important role in facilitating the transfer of risks (see Chapter 5). However, in the absence of broader risk management approaches, these mechanisms can unintentionally encourage investments in activities or locations at risk to current or future climatic hazards (Schäfer, Warner and Kreft, 2018[98]; Surminski and Oramas-Dorta, 2013[99]). This does not reduce the potential value of either measure. Rather, it highlights the importance of complementing risk management measures with incentives for economic actors to reduce their exposure to risks and take additional measures to reduce their vulnerability.

Tools to limit exposure to hazards

Decision makers have different tools and mechanisms that can help minimise exposure. The role of EWS in reducing the exposure of people to forecasted hazards has received a lot of political attention in recent years. The Sendai Framework for Disaster Risk Reduction, for example, emphasises multi-hazard EWS (UNDRR, 2015[100]). Despite this recognition for EWS, almost 90% of LDCs and SIDS identify EWS as top priority in their Nationally Determined Contributions to the United Nations Framework Convention on Climate Change (UNFCCC) (WMO, 2020[101]). This focus on EWS points to a potential policy or financing gap. EWS empower individuals and communities to take preventive measures in a timely manner. It has been estimated that they can save assets worth at least ten times their cost. Meanwhile, a 24-hour warning of a storm or heatwave can reduce damages by 30% (GCA, 2019[102]).

EWS also can be effective in communicating the risks and engaging local communities in generating early warning information (UNFCCC, 2020[103]). The overall effectiveness of EWS, however, depends on the capacity of individual stakeholders, as well as the broader national, regional and international systems. When key capacities are lacking or there are gaps in the EWS, the losses can be disastrous. In 2008, a system to forecast tropical cyclones was in place in the North Indian Ocean. However, the Indian Meteorological Department designated to issue official tropical cyclone forecasts and warning did not have a mandate to provide storm-surge forecasts. When Cyclone Nargis hit Myanmar, the death toll exceeded well above 100 000. Over 80% of deaths were related to the storm surge that washed away more than 100 villages (Webster, 2008[104]).

Regional and international mechanisms facilitate exchange of information. This can include, for example, information related to management of cross-border flood risk in river basins or of climate risks across shared terrains or landscapes such as mountainous areas. Regional and international mechanisms can also contribute to enhanced accuracy of the warnings. However, such mechanisms rarely have authority to trigger action (UNDP, 2019[105]). EWS are increasingly also used in the context of disaster risk financing as illustrated by their application in forecast-based financing, discussed in Chapter 5.

Box 4.5. Working with nature to reduce climate risks

Nature-based solutions (NbS) are measures to “protect, sustainably manage or restore nature, with the goal of maintaining or enhancing ecosystem services to address a variety of social, environmental and economic challenges” (OECD, 2020[106]). NbS can help reduce and manage the exposure and vulnerability of lives and livelihoods to climate risks. Protecting and restoring mangroves, seagrass beds and salt marshes, for example, can increase resilience to a range of climate change impacts, such as coastal erosion and flooding due to sea-level rise (SLR) (see Section 4.5). In urban areas, green infrastructure, such as urban forests, can reduce vulnerability to flooding from extreme rainfall events and exposure to heat stress (Seddon et al., 2020[107]).

A long-term perspective is needed for NbS given the time lag between implementation and materialisation of benefits. A 1992 storm caused significant flooding to South Seaside Park in New York. Recovery measures included a focus on building dunes with simple snow fence barriers to catch sand and native grasses to hold them in place (NRC, n.d.[108]). When Hurricane Sandy hit the same area in 2012, the dunes had become 7.5 metres high and 45 metres wide, large enough to reduce vulnerability from the impacts of the storm that devastated neighbouring coastal communities (Smallegan et al., 2016[109]). The success of the NbS projects led Congress to approve allocation of between one-third and one-half of Hurricane Sandy recovery funds to NbS focused on habitat restoration, green infrastructure and community resilience planning (FWS, 2019[110]).

NbS also have potential to mitigate greenhouse gas emissions, with recent estimates suggesting a rate of 10 gigatonnes of CO_2 per year,[1] greater than emissions in the global transportation sector (Griscom et al., 2017[111]). To achieve this potential, scaled-up action is needed to stop the destruction of ecosystems worldwide (Girardin et al., 2021[112]). Despite this potential, there are growing concerns that a focus on the mitigation potential of NbS risks delaying decarbonisation efforts since it enables corporations in particular to claim carbon neutrality without actually cutting emissions (Seddon et al., 2020[107]). The permanence of sequestration in ecosystems is also a concern.

NbS can also have potentially adverse impacts if poorly planned and implemented. Tree planting on natural grasslands and peatlands can disrupt biological and biogeochemical processes. This can reduce soil quality and the ecosystem’s ability to store carbon, negatively affecting grassland biodiversity (Friggens et al., 2020[113]). In Cambodia, a large-scale reforestation project for mitigation led to clearing diverse forest landscapes for acacia monocultures, displacing customary land users from access to land and forest resources (Scheidel and Work, 2018[114]). Harvesting and clearing plantations also release stored CO_2 back into the atmosphere every 10-20 years, whereas natural forests continue to sequester carbon for decades (Lewis et al., 2019[115]). The IUCN Global Standard for Nature-based Solutions aims to address the potential adverse impacts of NbS by providing parameters for defining NbS and a common framework for benchmarking progress.

The potential of NbS to help manage climate risks can also be uncertain. Ecosystems change over time, partly in response to pressures (e.g. climate change, pollution, invasive species, habitat loss, over exploitation) that affect their structure and function. This could have significant effects on their projected climate and biodiversity benefits. For example, peatlands that provide valuable ecosystem services through flood management are sensitive to climate change (Shuttleworth et al., 2019[116]).

A focus on risk sensitive land-use planning can also help address increased exposure to weather and climate hazards brought about by development, especially rapid urbanisation. Land management regulations can create both incentives and disincentives in guiding public and private investments. Risk sensitive land-use planning highlights the importance of public policies and institutions in managing the expansion of investments and settlements into areas exposed to hazards (Sudmeier-Rieux et al., 2015[76]).

Similar to EWS, preventive or *ex ante* efforts try to identify and address the drivers of exposure to reduce losses and damages. This may be complemented with targeted support to people and communities temporarily or permanently displaced by weather and climate hazards, or worse, who may need resettlement. In Nepal, for example, risk sensitive land-use planning approaches have contributed to significant growth in the generation of hazard, exposure and vulnerability data. These are essential for understanding the risks and developing complementary land-use plans to reduce and manage those risks (Hada, Shaw and Pokhrel, 2021[117]).

4.3.3. Reducing vulnerabilities to weather and climate hazards

The third component of the IPCC risk framework highlights the importance of reducing the underlying vulnerabilities of human and natural systems to weather and climate hazards. The exposure to hazards takes place in complex social, political and technical contexts within and across countries. Many LDCs, for example, rely primarily on natural resources for their domestic income. Large shares of the population are engaged in outdoor work. In some cases, they have limited financial capacity to adapt to a changing climate and to recover from climate-related hazards (Woetzel et al., 2020[118]).

Within countries, vulnerability is shaped by position in society and the ability to contribute to decision-making processes. Such processes include those that determine access to resources, assets and forms of social protection (Thomas et al., 2018[119]). Groups marginalised by, for example, their gender, race, age, disability, income, class identities, religion or geographic locations are particularly at risk (Eriksen et al., 2021[120]; Winsemius et al., 2015[121]). These contexts determine the ability of different segments of society to access resources that enable them to prepare for and recover from hazards. The resources, both tangible and intangible, include income, time, data and information, awareness and ability to access available resources, among others (Thomas et al., 2018[119]).

Climate vulnerability assessments aim to shed light on who or what is vulnerable to the impacts of climate change. They often focus on the vulnerability of infrastructure (e.g. transport and residential dwellings) and means of survival, and health (e.g. food supply and water). Less emphasis tends to be placed on understanding what determines those vulnerabilities. Issues such as poverty or lack of capacity are highlighted as potential drivers without necessarily being explored in sufficient depth (Ribot, 2014[122]). To address this challenge in the context of broader development, many African governments use the Household Economy Approach (HEA). The HEA aims to shed light on the drivers of vulnerability to poverty and food security (Seaman et al., 2014[54]; Acidri et al., 2018[55]) (as also mentioned in Box 4.3).

The economic, institutional and political drivers of vulnerability

Given the nature of vulnerability, it is important for policy makers to consider the impact of climate change on more intangible factors critical to maintaining social groups and networks. These factors range from social systems and informal networks to cultural knowledge and practices of daily life. The drivers of vulnerability have been categorised into three types of capacities – economic, institutional and political – each requiring tailored approaches (Thomas et al., 2018[119]).

Economic capacity encompasses income diversity and the ability to move between livelihoods or approaches within them. It can determine the impact of a shock on overall household wealth and well-being (Ahmed et al., 2019[123]). Marginalised segments of the population often live in areas more exposed to hazards. In the event of a disaster, then, the share of wealth lost by these segments tends to be relatively larger than for the rest of the population (Hallegatte et al., 2016[124]). In the absence of income diversity, savings or other sources of finance (e.g. insurance or social protection), marginalised households may resort to negative coping mechanisms. However, actions like taking children out of school, cutting consumption or selling productive assets could create poverty traps (Bowen et al., 2020[125]). Others may choose to migrate pre-emptively as an adaptation strategy or in response to climate impacts (see Box 4.6).

Box 4.6. Sea-level rise and migration

Increasingly, people around the world are feeling the impacts of climate change, and this will only grow stronger. In some cases, people will adapt to the impacts through migration; in others, they may be involuntarily displaced. Growing academic and policy interest in the linkages between climate change and human mobility is contributing to a more nuanced understanding of linkages between the two. While some research points towards increased human mobility due to climate change, others suggest vulnerable segments of the population could become less mobile in the face of growing hazards due to political and institutional constraints, lack of means or opportunities, among others (Black et al., 2013[126]). Yet others will be reluctant to migrate due to strong economic, cultural or social ties to a place (McLeman et al., 2021[127]). A focus on the impact of sea-level rise (SLR) on migration can shed light on the multitude of factors influencing these processes.

A large share of the global population resides in coastal areas where SLR will adversely affect well-being (McLeman, 2017[128]). SLR is projected to force millions of people inland if coasts are not protected (Lincke and Hinkel, 2021[129]), which in turn could trigger migration over further distances. Most estimates of global SLR this century fall below 2 metres (see Box 3.2). However, definitions of populations exposed to SLR differ. They include populations living in i) low-elevation coastal zones; ii) 100-year floodplains; or iii) areas that would be inundated under selected SLR scenarios (Hauer et al., 2019[130]). Around 190 million people occupy land below the projected high tide lines for 2100 under a low emissions scenario. This number increases to 630 million people by 2100 under a high emission scenario[1] (Kulp and Strauss, 2019[131]). The number of people exposed to SLR, however, is not the same as the number that will respond to SLR through migration. This is mainly because millions of people are protected against extreme sea levels and SLR. Still, as the climate continues to change, migration is likely to become more widespread (Oppenheimer et al., 2019[132]).

Migration is generally only one outcome that households and communities may choose in response to climate change (McLeman et al., 2021[127]). Similarly, climate change will only be one of a diverse set of factors contributing to decisions to migrate (Hauer et al., 2019[130]). The slow rate of change in SLR, in principle, provides people considerable time to put in place adaptation measures, in addition to efforts to limit SLR through mitigation (McLeman, 2017[128]). The triggering of tipping elements of the Earth system (see Chapter 3) could contribute to non-linear changes in ecological systems and a rapid acceleration of SLR later in the century. Migration patterns would be likely to respond in an equally non-linear fashion (McLeman, 2017[128]).

Although migration in response to SLR could have positive outcomes, it is generally perceived as disruptive to households, and in some cases community well-being as well. A decision to migrate therefore tends to happen in response to broader individual or household contexts. These include changes in assets, food security, or access to formal or informal support (McLeman et al., 2021[127]). Migration can anticipate adverse impacts of SLR or respond to them. Decisions made with greater agency are believed to have greater potential to generate positive outcomes in reducing vulnerability and building adaptive capacity. At the same time, urbanisation, as well as environmental resources and amenities provided by coastal areas, supports coastal developments and encourages migration towards coastal areas (Hauer et al., 2019[130]).

Note:[1] The low emissions scenario is consistent with the IPCC Representative Concentration Pathways (RCPs) 2.6; the high emission scenarios reflects RCP 8.5.

Peoples' vulnerabilities and lack of ***institutional capacities*** can transform hazards into disasters. When Hurricane Katrina hit the western coast of the United States in 2005, it struck an economically disadvantaged region recognised for significant and persistent multidimensional inequality. According to some analyses, the region's status stemmed from discriminatory policies and institutional practices towards Black communities over many years. These policies and practices affected labour markets, housing and mortgages, among others (Henkel, Dovidio and Gaertner, 2006[133]). At the time of Hurricane Katrina, the per capita and median household incomes of Alabama, Louisiana and Mississippi, the states most directly affected by the hurricane, were below the national average. Meanwhile, the share of the population in these states living in poverty was above average (Zottarelli, 2008[134]).

Economic marginalisation and discriminatory policies and practices were mutually reinforcing. The two drivers together meant the exposed population lacked the capacity or resources to take pre-emptive measures to adequately prepare for Katrina. Similarly, it was unable to take protective measures in response, such as by securing safe housing or relocating (Thomas et al., 2018[119]). These vulnerabilities were played out in the context of the built environment. Poorer segments of the population were more likely to settle in cheaper and less desirable coastal locations disproportionally exposed to weather and climate hazards. In terms of recovery, they were also relatively uninsured against floods (Henkel, Dovidio and Gaertner, 2006[133]).

Political capacity in the form of, for example, active participation in decision-making processes plays an important role in determining access to resources, policy approaches and decisions. Adaptation initiatives seek to strengthen the resilience of communities to the impacts of climate change. However, a review of adaptation-related development finance found they often failed to address the underlying drivers of individual or community vulnerabilities (Eriksen et al., 2021[120]). In some cases, adaptation finance inadvertently reinforced, redistributed or created new sources of vulnerability. Priorities determined by local elites, for example, can feed into existing power dynamics and reinforce inequalities. Alternatively, if not carefully managed, a hazard in one community can simply be transferred to different stakeholders (e.g. in the context of water or coastal infrastructure) (Eriksen et al., 2021[120]). Similarly, relocating people or communities can adversely affect social cohesion and sense of place. Decisions to adopt new agricultural practices to sustain production can similarly affect cultural values (Adger et al., 2012[135]).

This discussion highlights the importance of carefully grounding approaches to reduce and manage the risks of losses and damages from climate change in the context of an individual country or community. This process must be guided by a good understanding of the drivers that determine the level of economic, institutional and political capacity. This may not always be through climate-related initiatives. Instead, it could embrace approaches that foster broader sustainable developments, such as education, health or economic development.

Further, local knowledge of the risks and approaches to manage them must guide processes. Local actors, including Indigenous groups, have detailed knowledge on weather and climate hazards, the socio-economic context and local experiences of managing past weather- or climate-related events (ILO, 2017[136]). The UNFCCC recognises the role of Indigenous and local groups in the management of climate risks. The Local Communities and Indigenous Peoples Platform aims to facilitate exchange of experiences of different knowledge systems on climate action. It also seeks to enhance engagement of local communities and Indigenous peoples in the climate process (UNFCCC, n.d.[137]). The Africa Adaptation Initiative and the Least Developed Countries Initiative for Effective Adaptation and Resilience (see Box 4.7) are examples of processes owned and led by such groups at the regional level.

Box 4.7. Ownership and leadership of climate initiatives

Africa Adaptation Initiative (AAI)

AAI, an initiative of the African Union, was launched by African Heads of State at COP21 with three goals. First, it seeks to accelerate efforts to adapt to the adverse impacts of climate change. Second, it aims to strengthen collaboration on adaptation across the continent. Third, it works to galvanise support needed to significantly scale up adaptation efforts.

AAI takes a strategic view by identifying adaptation gaps and connecting regional partners, public and private. In this way, it aims to identify, refine and prioritise activities aligned with the four AAI pillars: i) enhancing climate information services; ii) strengthening policies and institutions; iii) enhancing on the ground action; and iv) climate finance and investments.

Nine guiding principles inform AAI initiatives: i) be stakeholder-driven; ii) be relevant to Africa; iii) build and strengthen new partnerships; iv) support African countries to engage with processes under the UNFCCC; v) promote regional and transboundary co-operation; vi) develop work packages in line with immediate, short, medium and long-term adaptation needs; vii) enhance communication; viii) employ a phased approach; and ix) promote transparency.

The Least Developed Countries (LDCs) Initiative for Effective Adaptation and Resilience (LIFE-AR)

LIFE-AR, led and owned by LDCs, was established in 2018 to develop a long-term vision for delivering a climate-resilient future in LDCs. The LDC Vision is for "LDCs to be on climate resilient development pathways by 2030 and deliver net-zero emissions by 2050 to ensure our societies and ecosystems thrive." LIFE-AR emerged from three beliefs: i) business-as-usual approaches to climate change are not working; ii) the adaptation and local level financing gap in developing countries is wide; and iii) short-term, project-based and sectoral-specific climate responses have limited impact. As such, it seeks to address these challenges and deliver the LDC Vision through long term, multi-sectoral, country led approaches that build country systems, knowledge, and capabilities, with access to predictable and reliable finance – domestic, international, public and private – that reaches the local level.

LIFE-AR is guided by the principles of inclusion, participation, local action, justice, equity and leaving no one behind. LDC governments have made a number of commitments that have been complemented by a set of asks by those governments to the international community as summarised in Table 4.3.

Table 4.3. Commitments and asks of LIFE-AR

Commitments by LDC governments	Ask of the international community
Will work with the whole of society to achieve a low-carbon, climate-resilient future	Provide high-quality, predictable and accessible finance to help LDCs deliver the SDGs and Paris Agreement. Support the LDCs' intention of at least 70% of financial flows supporting local-level action by 2030.
Will develop strong climate finance architecture, with at least 70% of flows supporting local-level action by 2030	Work together to reduce transaction costs and ensure mutual accountability behind LDC leadership.
Will integrate adaptation, mitigation and resilience into national and local development objectives	Work with LDCs in the long term to strengthen national and local institutional capabilities.
Will strengthen climate capabilities, institutions, knowledge, skills and learning	Invest in LDCs' climate-resilient net-zero economies and technology.
Will create more inclusive governance of climate decisions that are centred on gender transformation and social justice	Develop ambitious strategies (in developed countries) for 1.5°C low-carbon climate-resilient pathways by 2020.

Source: https://africaadaptationinitiative.org/; (LIFE-AR, 2019[138])

Gradual vs. transformative change

Actors are addressing their vulnerability in response to growing impacts from climate change. In most cases, this entails gradual adjustments to current practices. At the national level, examples include changes to land-use management, infrastructure development or sectoral strategies. At the individual or household level, livelihood choices can reduce vulnerability to weather and climate hazards. In Uganda, farmers of sweet potatoes are autonomously adjusting their practices to get the best yields possible. To that end, they are planting sweet potato varieties with shorter maturation periods in response to increasing uncertainty about the onset and cessation of the rainy seasons. In other contexts, more drastic, and in some cases transformative, changes are required.

In northern Kenya, some pastoralists have gone beyond adjustments to make more transformative changes. They have replaced cattle with camels that are better suited to the increasingly hotter climate with less predictable rainfall. Camels require less water, eat a wider variety of vegetation and produce up to six times more milk than local cattle species (Salman et al., 2019[139]; Volpato and King, 2018[140]). Over time, the market for camels and camel milk in Kenya has developed, boosting livelihoods and food security (Elhadi, Nyariki and Wasonga, 2015[141]). Like the Kenyan farmers switching from cattle to camels, some farmers in Costa Rica are switching from coffee to oranges. Oranges are better suited to warmer temperatures, and more profitable than coffee that is subject to increasing global competition. These farmers have also observed that oranges are more resilient to droughts, floods, temperature fluctuations, erratic rainfall and higher winds (Tye and Grinspan, 2020[142]).

The changes in Kenya and Costa Rica have occurred autonomously and without any government support. They responded to an evaluation of the suitability of new approaches to different climate futures. For such transformations to be sustainable, however, policy makers must play a more active role in working with the scientific, local and Indigenous communities. Together, they need to identify opportunities for action and develop policies and plans that make available information (including climate information), technical assistance (such as extension services) and financial resources supportive of the transition. In some cases, market policies (e.g. agricultural subsidies) will also have to be adjusted. This adjustment would promote climate-resilient products and approaches and support market creation for emerging products, such as camel milk, as needed (Salman et al., 2019[139]; Volpato and King, 2018[140]). Such adjustments, whether technical or financial, will require time to produce the same level of support as existing measures (Tye and Grinspan, 2020[142]). In the short term, mechanisms should enable individuals and private sector actors to better respond to climate hazards. These mechanisms could include, for example, clear strategic policy guidelines and support mechanisms aligned with those objectives.

4.4. Institutions, governance and norms for reducing and managing losses and damages

Efforts by different stakeholder groups to address the hazard, exposure and vulnerability will be guided by the institutions and governance processes in place. IPCC has identified three ways in which institutions shape and constrain climate policy making and implementation (Somanathan et al., 2014[143]):

- Institutions, whether with formal rules or informal norms, set incentive structures for economic decision making (e.g. in the context of transport investments or behavioural decisions relevant to efficient energy use).
- Institutions shape the political context for decision making, empowering some interests while reducing the influence of others (e.g. as reflected in the energy pricing or broader environmental taxing of some countries).

- Institutions influence how risks are perceived and valued, what risks are prioritised for action, and how they are addressed (i.e. what approaches are included or excluded from consideration and implementation).

Perceptions of climate risks, based on knowledge and previous experience, also guide the prioritisation and management of the risks. They identify which risks are tolerable, which should be addressed, by when and to what extent (Thomas et al., 2018[119]). Approaches to address the components of climate risks therefore are inevitably political, reflecting the diverse and conflicting values and interests of stakeholders. Governments and others in positions of authority may seek to shed light on the risks through policy consultation and co-ordination, research and other means. Individuals and communities will interpret the information and associated guidance mediated by their own perceptions of the risks. These perceptions may not be consistent with wider public concerns (Sudmeier-Rieux et al., 2015[76]). This is equally the case at the global level where countries perceive, experience and respond to global risks, including climate change, in different ways (White and Lawrence, 2020[144]).

Diverging interests and values contribute to delayed climate action. Differences between the economic incentive structures for mitigation action (a global public good) and adaptation (a range of local public goods, common pool resources and private goods) can delay action on climate or lead to inadequate responses. However, diverging interests and values, both nationally and internationally, are also factors. For example, groups with a vested interest in continued fossil fuel consumption have been instrumental in spreading doubt about the credibility of climate science (e.g. through disinformation campaigns).

Growing evidence suggests that climate action does not have to come at the expense of economic development (OECD, 2017[65]; OECD/The World Bank/UN Environment, 2018[145]). However, climate action at the ambitious scale needed to reduce risks of losses and damages will inevitably have winners and losers. At the national level, for example, economic activities may shift towards less fossil-fuel intensive alternatives or to those less vulnerable to weather and climate hazards. Due to this shift, some will lose their jobs, while others will find new opportunities. Similarly, across countries, trade patterns may change as companies seek to reduce their vulnerability to extreme weather events.

A just transition and decent work are becoming political priorities for climate action. Recognising the growing social impacts of climate change policy, decision makers have elevated a just transition of the workforce and the creation of decent work and quality jobs on the political agenda. The preamble to the Paris Agreement, for example, emphasises the “imperative of a just transition of the workforce and the creation of decent work and quality jobs in accordance with nationally defined development priorities” (UNFCCC, 2015[61]).

Policy makers have at their disposal different tools to make climate risks tangible and inform decision-making processes. Some tools raise awareness among different stakeholders on the nature of the risks and solutions for managing them. Others influence incentive structures for decision-making processes, such as one-off compensation, pricing or subsidies. Still others impose regulatory standards or prohibit certain practices such as land-use management or engineering design standards (Baer, Campiglio and Deyris, 2021[146]). The levers can be activated at different levels of governance and across stakeholder groups. The application of different tools, then, must be guided by transparency, a good understanding of the synergies, trade-offs and feedbacks between them. It must also respect the interaction of climate-related impacts with social, environmental and economic drivers across spatial and temporal scales (OECD, 2021[147]).

4.4.1. Governance arrangements for reducing and managing risks of losses and damages

Governance arrangements are central to the management of climate risks. Governance arrangements refer broadly to the structures and processes that steer society and the economy towards common objectives (Ansell and Torfing, 2016[148]). They differ across levels (local, national, regional, global) and modes of governance (market, network, hierarchy) (Jordan et al., 2015[149]). In the context of climate change, governance includes an explicit focus on the management of the hazards. In addition, it includes the broader set of structures and processes that shape the socio-economic context determining exposure and vulnerability of people and assets to different type of climate-related hazards.

As a global problem that depends on collective action to limit the increase in hazards, climate change poses challenges for effective international governance. For example, countries face differential risks. They have different national interests and perceptions of the costs and benefits of mitigation action. They also have large differences in political, economic and technological capacity. These issues have contributed to more emphasis on the risk management component of risk governance (Klinke and Renn, 2019[150]). Risk management approaches emphasise the complexity of and the uncertainties inherent in understanding risk. They also stress the ambiguity or different and sometimes divergent interpretations of the risks and their context (Klinke and Renn, 2019[150]).

Two recent approaches reflect a shift in focus from the distinct processes of risk assessment, risk management and risk communication towards the role of institutions and processes that guide and facilitate the management of the risks. The Sendai Framework for Disaster Risk Reduction identifies strengthened disaster risk governance as a priority for effective and efficient management of disaster risks. It "fosters collaboration and partnerships across mechanisms and institutions for the implementation of instruments relevant to disaster risk reduction and sustainable development" (UNDRR, 2015[100]). For its part, the OECD Council Recommendation on the Governance of Critical Risks also recognises the importance of a fundamental shift in risk governance towards a whole of society effort (OECD, 2014[151]). Table 4.4 summarises the recommendations and proposed areas of action outlined in the OECD Council Recommendation (2014[151]).

Adaptive or iterative approaches to governance of risks place emphasis on the importance of associated governance structures and institutional settings facilitating continuous monitoring, evaluation and learning (Klinke and Renn, 2012[152]; OECD, 2021[147]; Folke et al., 2005[153]). This can be informed by lessons learnt from management of previous or similar risks. It can also draw on emerging understanding of the risks and related technologies as they become available (Klinke and Renn, 2012[152]). Such approaches facilitate a continuous process of characterising risks. This will be critical in informing everything from evaluation of the risks to development, implementation and evaluation of approaches to reduce and manage those risks (IRGC, 2017[154]).

Both climate-related hazards and socio-economic contexts are dynamic and non-linear (see Chapter 2). Consequently, risk governance must assess the different processes and outcomes; their interactions (especially of any feedbacks that may amplify or reduce the effectiveness of measures); and any synergies and trade-offs. Such iterative processes can inform continuous adjustments of approaches based on emerging understanding of the risks and lessons learnt. Box 4.8 summarises the approach promoted by the German Federal Ministry for Economic Co-operation and Development in dealing with disaster and climate risks.

Table 4.4. OECD Council Recommendation on the Governance of Critical Risks

Recommendation	Action
Establish and promote a comprehensive, all-hazard and transboundary approach to risk governance to serve as the foundation for enhancing national resilience and responsiveness.	• Develop a national strategy for the governance of critical risks. • Assign leadership at the national level to drive policy implementation, connect policy agendas and align competing priorities across ministries and between central and local government. • Encourage all government actors at national and subnational levels to co-ordinate a range of stakeholders in inclusive policy-making processes. • Establish partnerships with the private sector to achieve responsiveness and shared responsibilities aligned with the national strategy.
Build preparedness through foresight analysis, risk assessments and financing frameworks to better anticipate complex and wide-ranging impacts.	• Develop risk anticipation capacity linked directly to decision making. • Equip departments and agencies with the capacity to anticipate and manage human induced threats. • Monitor and strengthen core risk management capacities. • Plan for contingent liabilities within clear public finance frameworks by enhancing efforts to minimise the impact that critical risks may have on public finances and the fiscal position of a country to support greater resilience.
Raise awareness of critical risks to mobilise households, businesses and international stakeholders and foster investment in risk prevention and mitigation.	• Encourage a whole-of-society approach to risk communication and facilitate transboundary co-operation using risk registries, media and other public communications on critical risks. • Strengthen the mix of structural protection and non-structural measures to reduce critical risks. • Encourage businesses to take steps to ensure business continuity with a specific focus on critical infrastructure.
Develop adaptive capacity in crisis management by co-ordinating resources across government, its agencies and broader networks to support timely decision making, communication and emergency response.	• Establish strategic crisis management capacities to prepare for unknown and unexpected risks that provoke crises. • Strengthen crisis leadership, early detection and sense-making capacity, and conduct exercises to support inter-agency and international co-operation. • Establish the competence and capacities to scale up emergency response capabilities to contend with crises that result from critical risks. • Build institutional capacity to design and oversee recovery and reconstruction.
Demonstrate transparency and accountability in risk-related decision making by incorporating good governance practices and continuously learning from experience and science.	• Ensure transparency regarding the information used to ensure risk management decisions are better accepted by stakeholders to facilitate policy implementation and limit reputational damage. • Enhance government capacity to make the most of resources dedicated to public safety, national security, preparedness and resilience. • Continuously share knowledge, including lessons learnt from previous events, research and science through post-event reviews, to evaluate the effectiveness of prevention and preparedness activities, as well as response and recovery operations.

Note: Each action area is complemented in the Council Recommendations with suggested approaches or areas of focus.
Source: (OECD, 2014[151]).

Box 4.8. Comprehensive risk management in German development co-operation

The German Federal Ministry for Economic Cooperation and Development (BMZ) promotes an approach to address climate and disaster risks in a comprehensive, integrated manner. BMZ pulls from a wide range of strategies and risk management instruments (see Figure 4.3). It combines both tried-and-tested and innovative instruments from the fields of climate change mitigation, adaptation, disaster risk management and social protection to form a single comprehensive risk management approach. Further, transitional development assistance acts as a bridge to humanitarian aid.

In practice, instruments are chosen specific to the given context. Early warning systems, for example, are implemented as a fundamental component of a preparedness strategy. The combination of adaptation measures such as ecosystem-based adaptation with risk transfer instruments can minimise the risk of losses and damages. Box 5.12 in Chapter 5 highlights the role of risk finance and insurance tools in more detail.

The approach encourages adopting a flexible process. This would be tailored to specific needs, contexts and scales, while also considering potential cascading effects. The comprehensive risk management approach supports both state and non-state actors to factor in all relevant risks when making decisions and implementing strategies and policies.

Figure 4.3. Comprehensive risk management: Strategies and instruments

Source: (BMZ, 2019[155])

Engaging stakeholders in an inclusive manner

An iterative approach requires the engagement and consideration of the perspectives of different stakeholder groups – public, private, formal and informal – including local and Indigenous groups. Each stakeholder contributes in a unique and complementary way to understand the risks, and to reduce and manage them according to its respective capacities and accepted functions (Schweizer and Renn, 2019[156]; IPCC, 2012[74]). Different stakeholders will have different resources and capacities to make their voices heard. Consequently, representation and participation on their own do not result in inclusive outcomes (OECD, 2021[147]). Mechanisms must therefore facilitate exchange of information to guide efforts towards a shared understanding of the risks and approaches to reduce and manage them.

For example, in Chile the establishment of a Roundtable on human mobility, climate change and disasters aims to address a governance gap given the increasing relevance of these issues for the country. The Roundtable engages a diverse set of stakeholders from the public, private, academia and civil society. The institutional arrangement facilitates enhanced understanding of the issues and their interlinkages to inform the development of guidelines for subnational governments.

The cascading and uncertain nature of climate risks means that the stakeholder community may not always be well defined. In some cases, it will cross geo-political jurisdictions (UNDRR, 2019[9]). With mounting risks of losses and damages, stakeholders may increasingly also need to make more radical or transformative changes to reduce hazard, exposure and vulnerability. Given climate change does not affect everyone in the same way, such processes must be guided by a widely-shared and robust public understanding of the risks and acceptance of the need for the proposed actions and approaches (UNDRR, 2021[157]). There will also be a political and ethical imperative for the governance system to manage these processes carefully and transparently. This could include careful assessment of distributional implications in advance. It could also include adoption of appropriate complementary compensation measures that can limit the adverse impact of policy measures and other efforts on peoples' well-being (OECD, 2019[158]).

Strategic, operational and technical co-ordination

Countries are increasingly also recognising the benefits of enhanced collaboration and coherence between climate and disaster risk reduction communities (OECD, 2020[57]; Haque et al., 2018[81]). Policy coherence viewed as a process of co-ordination can occur on a continuum – from the strategic to operational and technical levels (OECD, 2020[57]) (see Box 4.9). While increased coherence can improve efficiency and effectiveness, it can also lead to trade-offs between investing in enhanced coherence and enhancing individual policy processes (Dazé, Terton and Maass, 2018[159]). The theoretical rationale for coherence is not always reflected in practice, suggesting actual or perceived mismatches in processes and institutions. Mismatches can be due to several factors. The different institutional histories of the two approaches have contributed to separate institutional structures and funding mechanisms with different operational timescales. The immediate disaster response, for example, may be short term, whereas long-term perspectives are a key element of climate action (OECD, 2020[57]).

Emerging good practice in different country contexts, including the Philippines and Peru, is to establish high-level co-ordination. Such an approach should have the support of political leaders to reach a common understanding of enhanced coherence and how it can be achieved. In practice, key ministries, such as Finance, should ensure that the allocation of resources reflects the allocation of roles and responsibilities. National governments drive efforts to strengthen policy coherence. However, implementation usually occurs at the sector or local level. At these lower levels, capacity may be more limited and the actors in charge will face competing demands. National-level actors must therefore be aware of the burden that planning, implementing and monitoring such processes can place on different stakeholder groups (OECD, 2020[57]).

Box 4.9. Policy coherence: Climate change adaptation and disaster risk reduction

Coherence can be pursued and operationalised: i) horizontally across sectors, ii) vertically by bringing together different levels of government (local, subnational, national, regional and global), and iii) through collaboration across diverse stakeholder groups, from governments and intergovernmental organisations to the private sector, civil society organisations and citizens. These approaches can, in turn, be grouped into three types of coherence:

- ***Strategic (visions and goals)***: Aligned visions, goals and priorities on climate change and disaster risk reduction in national development plans and strategies, providing a framework for pursuing operational coherence. With aligned goals and objectives at the strategic level, the basis for coherence in implementation is strong.
- ***Operational (policy and institutions)***: Policy frameworks and institutional arrangements supportive of the implementation of aligned objectives on climate change and disaster risk reduction, limiting the burden on often stretched human, technical and financial resources. Linking the two agendas at the operational level through the development of effective policies and institutional arrangements can also prevent duplication of efforts, or conflicting activities.
- ***Technical***: Strengthened technical capacities to assess the risks and opportunities, to identify and prioritise climate change and disaster risk reduction measures, and to finance them. For example, adaptation planning can benefit from tools and information already well established in the disaster risk reduction community, such as risk assessments. Conversely, emerging evidence of good practice approaches to climate change can inform disaster risk mitigation measures, reducing the potential for maladaptation.

Source: (OECD, 2020[57]).

4.4.2. Norms and norm entrepreneurs

The role of norms in informing action, including on climate change, is often overlooked. Norms shape preferences, ideas and expectations; they have the potential to also support the integration of international policies and institutions (Galaz et al., 2017[160]). The precautionary principle, for example, calls for action to prevent serious or irreversible damage before harm can be scientifically demonstrated. For its part, the polluter pays principle argues those who pollute should also bear the costs of abating the pollution and preventing associated damages to humans or the natural environment (Munir, 2013[161]). Both principles have become key elements of international environmental law.

Norms are not static but emerge and diffuse until they are adopted by a critical mass of relevant actors (Galaz et al., 2017[160]). Events or triggers can contribute to changes in norms. At the national level, such a trigger could be a devastating extreme weather event or a series of repeated events with widespread losses and damages. Enhanced scientific understanding could also play this role. While some transitions happen relatively rapidly, others take much longer. The pace of change depends on technological, economic, commercial, political and social factors.

The outlawing of ozone-depleting substances (ODSs) is an example of a relatively rapid transition, facilitated by the ready availability of commercially viable substitutes for ODSs in most uses. The Montreal Protocol, which oversees the phasing out of the production and consumption of ODSs, differs from other international environmental agreements. Targets and timelines are complemented with mechanisms that limit incentives for countries to free ride through, for example, trade restrictions (Barrett, 2003[162]). In contrast, institutional inertia in phasing out fossil fuel-based power generation in contexts where the technology has matured and cleaner alternatives are cost competitive illustrates how technological maturity on its own is not enough for transitions to happen. Larger political economy issues may still dominate. In such cases, an explicit focus on the barriers for transition may be needed.

So-called norm entrepreneurs – academics, legal scholars and local and religious leaders to name a few – can help diffuse new norms by identifying the implications of different choices (Otto et al., 2020[163]). For example, with the publication of the encyclical *Laudato si*, Pope Francis used his role within the Catholic Church to highlight the moral imperative for all actors to act on climate change and the ethical implications of failing to do so.

In recent years, young people (individually and collectively) have played a critical role in bringing climate change to the attention of the broader public. They have called on governments to act in accordance with available science, while also highlighting the implications of individual consumption and lifestyle choices (Otto et al., 2020[163]). Over the coming years, members of the youth movement will have the opportunity to engage more directly in the political process, with the potential of bringing about radical change. This points to the important role of education, science and critical thinking in shaping norms. In addition, it highlights the importance of creating institutional structures that give youth and future generations status within policy processes. The Welsh Well-being of Future Generations Act, for example, resulted in the creation of a Future Generations Commissioner.

Time will tell what impact such norm entrepreneurs will have on climate action. However, government officials are increasingly realising the importance of addressing public concerns about the climate. The elections in Australia in 2019 (Colvin and Jotzo, 2021[164]) and Germany in 2017, for example, saw a broader spectrum of political parties include climate change in their programmes.

Civil plaintiffs are taking governments and corporations to court

Public engagement has also contributed to citizens taking governments or corporations to court for failing to take adequate climate action. Plaintiffs have globally brought over 1 500 climate-related lawsuits, with the numbers rising. In most cases, they seek compensation for climate-related losses to compel governments or corporations to take more ambitious climate action (Setzer and Byrnes, 2020[165]). While most claims to date have been unsuccessful, others – such as in Germany and the Netherlands – have influenced change:

- In April 2021, a German court ordered the government to rewrite the climate law. The court ruled that too much of the burden to cut emissions was placed on future generations (LSE, n.d.[166]). In response, the government of Germany adopted an amended Climate Change Act. It includes commitments to reduce GHG emissions by 65% compared to 1990 by 2030 (instead of 55%) and by 88% by 2040 (no prior goal). It also revised the target date for climate neutrality from 2050 to 2045.
- In May 2021, a Dutch court ordered Shell and its suppliers to cut emissions by 45% by 2030 from 2019 levels. The plaintiffs, representing over 17 000 Dutch citizens, argued that Shell's planned emissions reductions of 20% by 2030 violated human rights by fuelling climate crisis (LSE, n.d.[166]). This was the first time a court ordered a large corporation to increase its mitigation efforts. It sets a precedent, giving the public a tool to influence policy outcomes and corporate behaviour (Toussaint, 2020[167]; UNEP, 2021[168]).

In 2020, conversely, the UN Human Rights Committee dismissed a claim by a Kiribati citizen who had argued the effects of climate change displaced the people of Kiribati. The committee ruled that given the rate of SLR, the Republic of Kiribati, with help from the international community, can take "affirmative measures to protect and, where necessary, relocate its population" (UN Human Rights Committee, 2020[169]).

A review of 73 climate-related lawsuits found the evidence submitted often lags behind the state-of-the-art in climate science and that methodologies such as attribution science could inform future cases (Stuart-Smith et al., 2021[170]) (see Chapter 3).

Leadership, partnership and trust

Leadership and partnership are also important in informing change. Partnerships between the scientific and policy communities, for example, can help ensure that science informs approaches to reducing and managing climate risks. It is important to ensure that such partnerships are inclusive to different types of knowledge, including local and Indigenous knowledge. In this way, they can contribute towards a better understanding of the risks and help identify solutions considered legitimate by stakeholders (Cornforth, Petty and Walker, 2021[47]; UNDRR, 2021[157]).

The presence of trust among stakeholders determines whether such partnerships can bring about change. Some argue that stakeholders need to trust that effective public policy will be based on respect in preserving human dignity (Ascher, 2017[171]). Others suggest collaboration will be guided by a diversity of trust processes with affinitive trust playing a central role in the context of climate change (UNDRR, 2021[157]; Coleman and Stern, 2017[172]):

- rational trust, based on expected benefits and risks
- procedural trust, in fairness and integrity of the procedures involved
- affinitive trust, shaped by emotions, charisma, shared identities or feelings but not always longer-term interactions
- dispositional trust, signalling one's predisposition to trust another entity.

With the devastating impacts from climate change becoming increasingly apparent around the world, the emphasis on global solidarity has risen on the political agenda. This has already been written into the international climate process. Examples include: the goal of Paris Agreement to pursue efforts to limit the temperature increase to a range of well-below 2°C and towards 1.5°C above pre-industrial levels; the emphasis on common but differentiated responsibilities that underpins countries' Nationally Determined Contributions; and the requirement that developed countries provide finance and other means of implementation (technology and capacity development support) and lead efforts to reduce emissions. These goals, principles and responsibilities all reflect a sense of international solidarity. They articulate a conviction that collective action to reduce and manage the risks and impacts of climate change benefits all. An emphasis on solidarity in guiding climate action has also risen in the context of the humanitarian community facing increasing pressure to support countries experiencing direct losses and damages from climate change.

4.5. Implications of sea-level rise on policy priorities and decision-making processes in SIDS

This section explores the implications of SLR on decision-making processes and policy priorities in SIDS. It builds on the discussion in Chapter 3 that outlines the impact of SLR on SIDS, as well as on the preceding sections of this chapter. Chapter 3 highlighted that all SIDS are vulnerable to climate change irrespective of their diversity. This is especially true of SLR because the habitable areas are limited to the low-lying coastal zone. SIDS are also disproportionally affected by extreme weather events due to their geographic locations. With relatively undiversified economies and limited natural resources, SIDS risk extensive losses and damages from SLR.

The section first discusses the different types of responses to SLR and their relative strengths and weaknesses (Section 4.5.1). This is complemented with a discussion of potential policy priorities and decision-making processes for addressing SLR in SIDS (Section 4.5.2).

4.5.1. Responses, their strengths and weaknesses

There is no silver bullet to reducing and managing the risk of SLR and associated changes in extreme sea levels, coastal flood hazard, coastal erosion hazard, loss of ecosystems and freshwater resources. There are diverse responses to SLR, each with its strengths and weaknesses. It is therefore useful to consider their complementary roles in an integrated response to SLR. Four fundamentally different types of responses have been identified (Nicholls et al., 2007[173]; Oppenheimer et al., 2019[132]; Wong et al., 2014[174]), each briefly described below. The responses complement the discussion on approaches to address the drivers of exposure and vulnerability to hazards discussed in Section 4.3.

Protection, advance, accommodation and retreat

Protection reduces the chances of coastal hazards (SLR, surges, waves) propagating inland and causing damages to people, their livelihoods and built environment. Protection can be delivered in three ways:

- Hard engineering structures, such as dykes, seawalls and breakwaters, can be built.
- Sediment-based measures can replace eroded sand to nourish beaches and shores.
- NbS can use coastal ecosystems such as reefs, mangroves and salt marshes as buffers.

In this way, NbS can attenuate extreme sea levels (surges, waves); reduce rates of erosion; and raise elevation or create new land by trapping sediments and building-up organic matter and detritus (Pontee et al., 2016[175]; Spalding et al., 2013[176]; Temmerman et al., 2013[177]). The use of seawalls – as one hard coastal protection structure – is widespread in SIDS. These are vertical walls built along the coastline to prevent flooding and erosion (Betzold and Mohamed, 2016[178]).

Advance also aims at preventing the coastal hazard from propagating inland but this time by building new land seawards and upwards. For SIDS, this means reclamation of new land or new islands at higher elevation levels. Land reclamation is widely practised around coastal cities where land is scarce and valuable, including on SIDS. Newly reclaimed land is, however, not necessarily elevated. This may even constitute maladaptation by increasing the exposure to coastal hazards. Globally, about 34 000 km^2 of land has been gained from the sea during the last 30 years. The biggest gains are in places like Dubai, Singapore and China (Donchyts et al., 2016[179]; Martín-Antón et al., 2016[180]). The global area of atoll islands has increased by 62 km^2 from 2000-20, which is roughly twice the size of Tuvalu (Holdaway, Ford and Owen, 2021[181]). The largest increase in land areas of SIDS is found in the Maldives (38 km^2). On the islands of Hulhumalé, for example, land has been reclaimed on a reef flat next to the capital island of Malé. It reaches an elevation about 60 cm higher than Malé to account for future SLR (Brown et al., 2019[182]).

Accommodation, a third approach, refers to a wide array of measures that reduce the vulnerability of coastal residents, their livelihoods and the built environment. As such, it does not prevent coastal hazards from propagating inland. Documented accommodation measures for SIDS include the strengthening and elevation of houses, installation and upgrade of water storage, preservation of food for disasters, a switch to different salinity-tolerant crops, capacity building and awareness raising (Klöck and Nunn, 2019[183]; Mycoo and Donovan, 2018[184]).

Retreat, the fourth response, reduces or eliminates exposure by moving people, infrastructures and human activities out of the coastal risk zone (Hino, Field and Mach, 2017[185]). In Europe and the United States, retreat is often considered to be a coastal adaptation measure. The land retreated acts as a buffer zone attenuating extreme sea levels and, hence, reducing flood risk for the hinterland (Rupp-Armstrong and Nicholls, 2007[186]). Conversely, the literature on SIDS, as summarised in the IPCC Special Report on the

Oceans and the Cryosphere, generally views retreat as loss and damage rather than adaptation. This is because retreat means to give up scarce land or even to abandon entire islands (Oppenheimer et al., 2019[132]). Given the vulnerability of SIDS to disasters, as discussed in Chapter 3, many cases of abandoning islands are documented, including in response to disasters that are not climate-related. Examples include disasters caused by extreme sea levels, such as after the 2004 Indian Ocean tsunami in the Maldives (Gussmann and Hinkel, 2020[187]), volcanic eruptions, such as in Manam in Papua New Guinea (Kelman, 2015[188]), or tectonic land subsidence, such as in northern Vanuatu (Ballu et al., 2011[189]).

All four biophysical response measures are combined with, or initiated through, institutional arrangements that prescribe, recommend or incentivise certain measures (see Section 4.4). Such arrangements have not been the focus of much research on SIDS. Documented institutional responses in SIDS include restriction of access and resource use; efforts to mainstream climate change considerations into national plans and insurance; building codes for flood proofing houses; monetary incentives for risk transfer (e.g. subsidised insurance); or information provision through flood EWS (Klöck and Nunn, 2019[183]; Leal Filho et al., 2021[190]; Robinson, 2020[191]; Mycoo and Donovan, 2018[184]).

Further, research on the risk management experiences of SIDS is far from comprehensive. Recent systematic reviews highlight a focus of the literature on only a small number of SIDS. Pacific SIDS have received the most attention. Research has thereby focused on the main islands at the expense of remote and rural islands (Klöck and Nunn, 2019[183]). Generally, the focus has either been on hard measures or behavioural change. Most responses have been documented as reactive (i.e. after a disaster has occurred). They focus on current extremes rather than future climate change (Klöck and Nunn, 2019[183]). Generally, there is a lack of studies that have evaluated the effectiveness of these responses in SIDS (Gussmann and Hinkel, 2021[192]; Klöck and Nunn, 2019[183]).

Hard vs. soft protection

The question of hard engineering versus soft NbS to protect coasts from extreme sea-level events and SLR has provoked much discussion. Scientific and grey literature often advocates NbS as the solution to coastal adaptation. Conversely, it portrays hard protection measures such as seawalls to be bad, incremental and unsustainable. This is not a useful distinction. Both play complementary roles, and are often combined in so-called hybrid approaches (OECD, 2020[106]).

Hard protection has both strengths and weaknesses. One strength is the need for less space. They are also more reliable and predictable for flood security than many NbS, which vary more over time and space depending on the context (Narayan et al., 2016[193]; Pinsky, Guannel and Arkema, 2013[194]; Quataert et al., 2015[195]). As one weakness, hard protection, in particular on coral islands, interrupts the natural sediment transport from coral reefs onto island shores and surfaces that protect the islands from flooding and erosion in the first place.

NbS provide co-benefits beyond coastal protection such as carbon sequestration, improved water quality, biodiversity, fisheries and other resources (Oppenheimer et al., 2019[132]) (see Box 4.5). Furthermore, NbS can autonomously maintain their effectiveness by naturally adapting to rising sea levels. They can do this through raising land and migrating inland, provided sufficient sediment and inland space is available. In addition, some NbS have been demonstrated to be cheaper than hard measures. Ferrario et al. (2014[196]), for example, found the costs of restoring reefs significantly lower than building artificial breakwaters.

However, many comparisons between the two approaches ignore the opportunity cost of NbS. Opportunity costs of NbS are generally higher, at least in the short term. They often need a lot of space that could be developed into profitable usages of land. In fact, mangrove forests are being destroyed at alarming rates of 4-9% per year (Duarte et al., 2008[197]) primarily because conversion of mangroves into agriculture, shrimp farming or industrial usages is profitable in private terms in the short term (Li et al., 2013[198]).

These strengths and weaknesses mean that different approaches apply in different contexts. For urban and densely populated areas, hard protection has played a central role, and will continue to do so. Many cities around the world, including in SIDS, are protected by hard infrastructure. If there is limited space and large human values are at risk, the continuation of hard protection makes a lot of sense. Even under 21st century high-end SLR, hard protection is highly cost-efficient for cities and densely populated areas (Hallegatte et al., 2013[199]; Lincke and Hinkel, 2021[129]; Tiggeloven et al., 2020[200]). Conversely, rural and sparsely populated islands have more land available and hence may greatly benefit from a focus on NbS.

For coral SIDS, NbS may be favoured for those islands that still have the natural capacity to grow with SLR. These are islands where the natural patterns of sediment production and transport are functioning (see Chapter 3). Introducing hard measures in these environments would ultimately destroy these natural mechanisms, locking the islands into hard development pathways (Duvat and Magnan, 2019[201]). However, NbS may not be recommended for all islands. Islands already heavily modified by humans are nearly impossible to return to their natural morph dynamics. This includes the main and capital islands of many coral SIDS, such as Malé in the Maldives or Vaiaku/Funafuti of Tuvalu. Here, hard protection measures play an important role. However, even urban islands need to maintain a healthy and functioning reef to grow upwards with SLR. These reefs reduce wave energy and heights, making it more affordable and technically much easier to protect the islands against SLR.

Advance vs. retreat

As a general weakness, protection always leaves a residual risk. Both soft and hard protection may fail. Furthermore, extreme sea-level events can exceed protection standards. For that reason, flood damage cannot be completely excluded. In addition, if flood defences are raised with rising SLR, the risk of extreme disasters increases. In the case of defence failure damages will be large due to deep floodplain behind the defence (Hallegatte et al., 2013[199]). The risk of failure can be reduced to almost zero through wide flood defences known as unbreachable dykes (De Bruijn, Klijn and Knoeff, 2013[202]). However, these require a lot of space generally not available for SIDS.

The advance approach offers several strengths. Residual risks can be partially avoided through advance, if newly constructed islands are reclaimed at a sufficiently high level. Under moderate to high SLR, for example, the Maldivian island of Hulhumalé can avoid wave-induced flooding until the end of the century (Brown et al., 2019[182]). As another strength, advance creates new land, which is generally scarce in SIDS. For urban SIDS, advance can help overcome financing barriers. High, up-front investments in the creation of new, better protected land can be recuperated within a few years through real-estate revenues generated from newly created land (Bisaro et al., 2019[203]). The return on investment on such urban advance is shorter and less risky compared to investments in normal coastal protection. This makes it easier to attract finance for advance. Advance also has weaknesses. These include negative environmental externalities and the interruption of natural sediment dynamics, which generally leads to erosion either on the newly created land or in adjacent localities. In atoll islands, new land is often created on the reef flat, which reduces or eliminates its ability to attenuate waves.

With sufficiently high ground available, retreat can avoid residual risks. However, retreat is generally socially and politically contested for several reasons. First, there are vested coastal interests, including tourism and real estate sectors. Second, it raises difficult questions around equity and compensation. Third, there are frequent adverse outcomes, including disruption of livelihoods, loss of culture and identity, and psychological harm (Hauer et al., 2019[130]; Siders, Hino and Mach, 2019[204]).

4.5.2. Policy priorities and decision-making processes

This section presents six complementary policy priorities and decision-making processes that can be considered for addressing SLR in SIDS. It builds on discussions in both this chapter and Chapter 3.

International policy priorities

At the international level, the most important policy priority is mitigation of GHG emissions. Only stringent mitigation can reduce the risk of multiple metres of SLR and its catastrophic consequences on SIDS. SIDS may have more capacity to respond to SLR than often suggested in the media. However, unmitigated climate change and SLR threatens the survival of many SIDS. This is especially true for coral islands with elevations of only 2-3 metres above mean sea levels. These SIDS face the threat of higher and more energetic waves directly hitting the coast and over washing the islands because their natural protection through coral reefs is lost through ocean warming.

A second international policy priority is the need to support SIDS in meeting the cost of adaptation and reconstruction of lifeline infrastructure, assets and livelihoods. No matter the level of mitigation, sea levels will continue to rise, even if the temperature goal of the Paris Agreement is met. This is due to the delayed response of the ocean to global warming (Church et al., 2013[205]; Oppenheimer et al., 2019[132]). Even low-end SLR requires substantial investments in adaptation on SIDS and the risk of losses and damages will grow. Extreme sea levels and other natural hazards impact large fractions of the GDP of many SIDS. This means they have low capacity to finance adaptation and other activities to reduce and manage the risk of losses and damages. Consequently, international efforts to support SIDS are needed (Klöck and Nunn, 2019[183]; OECD, 2018[206]) (see Chapter 5).

Implementation of low-regret measures

From national to local levels, one immediate and generally recognised policy priority is the implementation of no- or low-regret measures. Although their meaning depends on context, no- or low-regret measures include some accommodation and disaster preparedness measures such as emergency planning and EWS. On the plus side, these accommodation measures produce almost immediate net benefits. Multi-hazard EWS have one of the highest benefit-cost ratios. However, these measures alone are only effective for current conditions and small rises in sea level. Hence, they eventually need to be combined, upgraded or replaced with other responses such as coastal protection.

Another low-regret measure is the consideration retreating from individual islands in an archipelago SIDS. Although it is generally disturbing to think of retreat as a no or low regret option, and recognising that what is considered “low regret” will vary across stakeholder groups, there are instances in which retreat may be considered as such. One instance may be in the aftermath of a coastal disaster where reconstruction of livelihoods in their original situation may cost as much as relocation to another island. Experiences after the 2004 Indian Ocean tsunami in the Maldives also show that the affected population may support a retreat under such circumstances (Gussmann and Hinkel, 2020[187]). Relocation may also cause relatively low regret when islands already have small and declining populations. In these cases, people are migrating to seek opportunities in the centre islands of archipelagos (Speelman, Nicholls and Dyke, 2016[207]). In both instances, relocating and concentrating population on fewer islands can bring both development and adaptation benefits; government services and coastal adaptation can be provided more efficiently to a population concentrated on a fewer number of islands.

Finally, some low-regret adaptation measures result from SLR and climate impacts being co-determined by non-climate, local drivers that can be addressed to reduce current and future climate risks. Natural sediment supply and transport processes can be maintained to reduce erosion impacts. Water pollution and tourism activities can be reduced to preserve coral reefs and reduce wave impacts. Mangroves can be preserved to reduce both surge and wave impacts. Finally, sufficient accommodation space can be maintained for mangroves to migrate inland with SLR (Duvat and Magnan, 2019[201]; McLean and Kench, 2015[208]) (see also Chapter 3).

Keeping future options open

Given the large uncertainty about SLR, it is important to keep future options open (Hallegatte, 2009[209]; Hinkel et al., 2019[210]). Long-term decisions that can wait, for example, can be postponed. Many retreat decisions for urban areas in SIDS fall under this category (Oppenheimer et al., 2019[132]). SLR may rise by multiple metres, posing existential threats to SIDS. However, there is also a substantial chance that SLR may stay below 40 cm by 2100 (50th percentile of RCP2.6) if the temperature goals of the Paris Agreement are met. Adapting to the latter amount of SLR is technically feasible in most places and also economically efficient in densely populated and urban areas. Hence, a meaningful strategy for urban areas may be to wait and observe how SLR observations and projections develop over the next decades. This could provide a better basis for an existential decision such as retreat (Hinkel et al., 2019[210]). Such waiting should, however, accompany the two priorities of contingency planning and iterative policy cycles.

Another way of keeping future options open is through flexible options that can be upgraded or changed once more is known about future SLR (see also Section 4.2). This is generally an argument for implementing NbS, including sediment-based measures instead of hard measures. NbS can, to some extent, self-adjust to future SLR. Sediment-based measures provide the flexibility to increase protection by applying more sand as the consequences of SLR unfold. Flexibility can also be built into hard infrastructure. Germany, for example, builds coastal dykes with a wider crest than necessary. This allows dykes to be raised further at low costs if SLR turns out to be higher than anticipated (MELUR-SH, 2012[211]).

Consideration of SLR in decisions that need to be made today

Many long-term decisions must be made today. Given the coastal nature of SIDS, many of these decisions are related to SLR. This includes long-term decisions on critical infrastructure, coastal protection, land-use planning and land reclamation, which can have time horizons of decades to over a century. Many of the urban centres of SIDS, for example, face high population pressures and an associated shortage of land for housing. This needs to be addressed today, and is frequently done by creating new land or islands. Long-term decisions are also needed around spatial planning. It might be beneficial, for example, to decide immediately which areas or islands should be further developed and which should be left undisturbed. This would allow the natural processes, which enable islands to self-adjust to SLR, to prevail.

Factoring in SLR into such decisions is beneficial, but the crucial question is how much SLR to consider. Sea-level science can only give a partial answer. The other part depends on the uncertainty preferences of the stakeholders. Box 3.2 (Chapter 3) highlights decision-making processes related to tolerance of risk and uncertainty. When stakeholders are uncertainty-tolerant and the value at risk is relatively low, the IPCC *likely* ranges provide a good basis for decision making (Oppenheimer et al., 2019[132]). If stakeholders are less tolerant towards uncertainties, then high-end SLR should also be considered. In these cases, there remains a 17% chance that SLR will be above the likely range of the IPCC scenarios. In many urban contexts where number of people and assets exposed to SLR and extreme sea levels is high, people are highly intolerant towards uncertainty. In this case, decision making should consider high-end SLR futures (Hinkel et al., 2019[210]).

Adaptive policy making and monitoring

Another priority is to set up iterative policy cycles for decisions and policies to respond to the extent of changes, together with supportive monitoring systems. This corresponds to “adaptive policy making” or “adaptive planning”, which respond to decision making under uncertainty and ambiguity (Walker, Haasnoot and Kwakkel, 2013[212]; Walker, Rahman and Cave, 2001[213]), as found in the context of SLR (also discussed in Section 4.2). Essentially, such adaptive approaches implement low-regret options and flexible measures today. They then monitor SLR, extreme sea levels and other decision-relevant variables so they can identify when in the future decisions and new policies must be taken. Importantly, a monitoring strategy should help identify needed shifts in policy early enough to allow sufficient time for planning and implementation before negative impacts occur (Hermans, et al., 2017).

Contingency planning for the worst to come

Contingency planning, the final policy priority, goes along with keeping future options open and adaptive. It explores what kind of responses are available and how these could be sequenced in the worst case scenario of high-end SLR. If SLR does follow a worst case trajectory, there may be a future moment in time after which there will not be sufficient time to plan and implement some responses, as these may take decades to plan and implement (Haasnoot et al., 2020[214]). In the context of SIDS, contingency plans include large-scale retreat responses. Retreating whole island states involves many difficult ethical, political, technical, humanitarian and legal aspects (Kelman, 2015[188]; Yamamoto and Esteban, 2014[215]). While many SIDS recognise the possible long-term existential threat of SLR, few countries have so far engaged in contingency planning (Thomas and Benjamin, 2018[216]). In 2014, former president of Kiribati, Anote Tong, initiated a long-term contingency plan to buy land on Fiji for relocating Kiribati's people. However, the plan was later undone by the new president (Kupferberg, 2021[217]).

An inexpensive tool for contingency planning is adaptation pathway analysis (Haasnoot et al., 2013[32]; Haasnoot et al., 2012[218]). This process has gained popularity in coastal contexts with prominent applications for London (Ranger, Reeder and Lowe, 2013[219]), the Netherlands (Haasnoot et al., 2020[214]) and Bangladesh (Government of Bangladesh, 2018[35]) (see also Box 4.2). However, there have been few applications in SIDS. As one possible outcome, the exercise may find that nothing needs to be done now. Instead, it could identify critical decisions to be taken once a certain level of SLR has occurred.

How will policy priorities change over time?

As sea levels continue to rise over the next decades, the policy priorities listed above will change. raising the critical question of if and when SIDS' adaptive capacities will be overwhelmed and they need to switch from a policy mix that combines protect, advance and accommodate to a retreat. Small-scale retreat may play a role in certain circumstances as a low-regret measure today. Large-scale retreat should be considered in contingency planning, but it will in most cases be too early to implement it. However, if sea levels continue to rise unabated, SIDS will eventually need to switch to a large-scale retreat policy (Kelman, 2015[188]).

Efforts to pin down when adaptation limits will be reached or to identify a specific level of SLR have been elusive (Leal Filho et al., 2021[190]; Nurse et al., 2014[220]; Oppenheimer et al., 2019[132]). Some work has conjectured concrete limits, including that most atolls will be uninhabitable by the mid-21st century (Storlazzi et al., 2018[221]). However, these projections have not considered human adaptation responses. Hence, they do not provide a comprehensive assessment. Conversely, assessments that include human dimensions and adaptation have not estimated absolute limits of adaptation in the context of SLR in SIDS (Oppenheimer et al., 2019[132]).

One conclusion that can, however, be drawn is that social, economic and financial limits to adaptation may be reached (long) before technical adaptation limits arise (Hinkel et al., 2018[222]). In principle, there are many technical options available for adapting even to 21st century high-end SLR. These include island raising and construction (Yamamoto and Esteban, 2014[215]); artificial breakwaters substituting the lost protective effects of corals, salt water desalination or import of potable water (Falkland and White, 2020[223]); or even floating islands (Marris, 2017[224]). Implementing these options at significant scales is costly and it is unlikely that SIDS can mobilise and access sufficient domestic and international funds and finance for this (Hinkel et al., 2018[222]; Oppenheimer et al., 2019[132]). Even if SIDS could afford the transformation to such radically different and completely engineered living environments, much of the rich cultural diversity and heritage tied to the natural environment of SIDS would be lost.

References

Acidri, J. et al. (2018), "Uganda – Synthesising evidence for targeted national responses to climate change", *Briefing Note*, No. WIBN0218/01, Walker Institute, University of Reading, United Kingdom, http://dx.doi.org/10.5281/ZENODO.3510110. [55]

ADB (2014), "Bangladesh could see climate change losses reach over 9% of GDP – Report", News Release, 19 August, Asian Development Bank, Manila, https://www.adb.org/news/bangladesh-could-see-climate-change-losses-reach-over-9-gdp-report. [93]

Adger, W. et al. (2012), "Cultural dimensions of climate change impacts and adaptation", *Nature Climate Change*, Vol. 3/2, pp. 112-117, http://dx.doi.org/10.1038/nclimate1666. [135]

Ahmed, I. et al. (2019), "Climate change, environmental stress and loss of livelihoods can push people towards illegal activities: A case study from coastal Bangladesh", *Climate and Development*, Vol. 11/10, pp. 907-917, http://dx.doi.org/10.1080/17565529.2019.1586638. [123]

Ali, G. (ed.) (2021), "Australian voters' attitudes to climate action and their social-political determinants", *PLOS ONE*, Vol. 16/3, p. e0248268, http://dx.doi.org/10.1371/journal.pone.0248268. [164]

Ansell, C. and J. Torfing (2016), *Handbook on Theories of Governance*, Edward Elgar Publishing, Cheltenham, United Kingdom, http://dx.doi.org/10.4337/9781782548508. [148]

Ascher, W. (2017), *Understanding the Policymaking Process in Developing Countries*, Cambridge University Press, Cambridge, United Kingdom, http://dx.doi.org/10.1017/9781108277990. [171]

Baer, M., C. Campiglio and J. Deyris (2021), "It takes two to dance: Institutional dynamics and climate-related financial policies", *Working Paper*, No. 384/386, Centre for Climate Change Economics and Policy/Granta Research Institute on Climate Change and the Environment. [146]

Ballu, V. et al. (2011), "Comparing the role of absolute sea-level rise and vertical tectonic motions in coastal flooding, Torres Islands (Vanuatu)", *Proceedings of the National Academy of Sciences*, Vol. 108/32, pp. 13019-13022, http://dx.doi.org/10.1073/pnas.1102842108. [189]

Barrett, S. (2003), *Environmental and Statecraft: The Strategy of Environmental Treaty-making*, Oxford University Press, United Kingdom. [162]

Betzold, C. and I. Mohamed (2016), "Seawalls as a response to coastal erosion and flooding: A case study from Grande Comore, Comoros (West Indian Ocean)", *Regional Environmental Change*, Vol. 17/4, pp. 1077-1087, http://dx.doi.org/10.1007/s10113-016-1044-x. [178]

Bhave, A. et al. (2016), "Barriers and opportunities for robust decision making approaches to support climate change adaptation in the developing world", *Climate Risk Management*, Vol. 14, pp. 1-10, http://dx.doi.org/10.1016/j.crm.2016.09.004. [30]

Bisaro, A. et al. (2019), "Leveraging public adaptation finance through urban land reclamation: Cases from Germany, the Netherlands and the Maldives", *Climatic Change*, Vol. 160/4, pp. 671-689, http://dx.doi.org/10.1007/s10584-019-02507-5. [203]

Black, R. et al. (2013), "Migration, immobility and displacement outcomes following extreme events", *Environmental Science & Policy*, Vol. 27, pp. S32-S43, http://dx.doi.org/10.1016/j.envsci.2012.09.001. [126]

Black, R. et al. (2021), *Taking Stock: A Global Assessment of Net Zero Targets*, Energy & Climate Intelligence Unit and Oxford Net Zero, London, https://eciu.net/analysis/reports/2021/taking-stock-assessment-net-zero-targets. [64]

BMZ (2019), *Comprehensive Risk Management: The Approach of German Development Cooperation for Dealing with Disaster and Climate Risks*, German Federal Ministry of Economic Cooperation and Development, Berlin. [155]

Bowen, T. et al. (2020), *Adaptive Social Protection: Building Resilience to Shocks*, Washington, DC: World Bank, http://dx.doi.org/10.1596/978-1-4648-1575-1. [125]

Brown, S. et al. (2019), "Land raising as a solution to sea-level rise: An analysis of coastal flooding on an artificial island in the Maldives", *Journal of Flood Risk Management*, Vol. 13/S1, http://dx.doi.org/10.1111/jfr3.12567. [182]

Buckle, S. et al. (2020), "Addressing the COVID-19 and climate crises", *OECD/IEA Climate Change Expert Group Papers*, No. 2020/04, OECD Publishing, Paris, http://dx.doi.org/10.1787/50abd39c-en. [70]

Burgin, L., D. Rowell and J. Marsham (2020), *Possible Futures for East Africa under a Changing Climate: Technical Appendix for HyCRISTAL's Climate Risk Narratives (Version 1)*, Zenodo, http://doi.org/10.5281/zenodo.3620757. [51]

Burgin, L. et al. (2019), *FCFA HyCRISTAL Climate Narrative Rural Infographic and Brief*, Zenodo, http://doi.org/10.5281/zenodo.3257288. [50]

Challinor, A. et al. (2018), "Transmission of climate risks across sectors and borders", *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, Vol. 376/2121, p. 20170301, http://dx.doi.org/10.1098/rsta.2017.0301. [12]

Chapman, M. (ed.) (2016), "The effectiveness, costs and coastal protection benefits of natural and nature-based defences", *PLOS ONE*, Vol. 11/5, p. e0154735, http://dx.doi.org/10.1371/journal.pone.0154735. [193]

Chen, J. and V. Mueller (2018), "Coastal climate change, soil salinity and human migration in Bangladesh", *Nature Climate Change*, Vol. 8/11, pp. 981-985, http://dx.doi.org/10.1038/s41558-018-0313-8. [92]

Church, J. et al. (2013), "Sea Level Change", in Stocker, T. et al. (eds.), *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, United Kingdom and New York, NY. [205]

Clarke, D. et al. (2018), "Prospects for agriculture under climate change and soil salinisation", in *Ecosystem Services for Well-Being in Deltas*, Springer International Publishing, Cham, http://dx.doi.org/10.1007/978-3-319-71093-8_24. [91]

Coleman, K. and M. Stern (2017), "Exploring the functions of different forms of trust in collaborative natural resource management", *Society & Natural Resources*, Vol. 31/1, pp. 21-38, http://dx.doi.org/10.1080/08941920.2017.1364452. [172]

Cornforth, R., D. Clegg and E. Petty (2021), *The Integrated Database and Applications for Policymakers (Version v2.0)*, Zenodo, http://doi.org/10.5281/zenodo.5025211. [56]

Cornforth, R., C. Petty and G. Walker (2021), "Supporting climate-resilient planning at national and district levels: A pathway to multi-stakeholder decision-making in Uganda", in *Climate Risk in Africa*, Springer International Publishing, Cham, http://dx.doi.org/10.1007/978-3-030-61160-6_8. [47]

Dazé, A., A. Terton and M. Maass (2018), *Coordinating Climate-Resilient Development Alignment to Advance Climate-Resilient Development. Overview Brief 1: Introduction to Alignment*, NAP Global Network, http://napglobalnetwork.org/wp-content/uploads/2018/08/napgn-en-2018-alignment-to-advance-climate-resilient-development-overview-brief.pdf. [159]

De Bruijn, K., F. Klijn and J. Knoeff (2013), *Unbreachable Embankments? In Pursuit of the Most Effective Stretches for Reducing Fatality Risk*, Taylor & Francis Group. [202]

Donchyts, G. et al. (2016), "Earth's surface water change over the past 30 years", *Nature Climate Change*, Vol. 6/9, pp. 810-813, http://dx.doi.org/10.1038/nclimate3111. [179]

Duarte, C. et al. (2008), "The charisma of coastal ecosystems: Addressing the imbalance", *Estuaries and Coasts*, Vol. 31/2, pp. 233-238, http://dx.doi.org/10.1007/s12237-008-9038-7. [197]

Duvat, V. and A. Magnan (2019), "Rapid human-driven undermining of atoll island capacity to adjust to ocean climate-related pressures", *Scientific Reports*, Vol. 9/1, http://dx.doi.org/10.1038/s41598-019-51468-3. [201]

Duvat, V. et al. (2017), "Trajectories of exposure and vulnerability of small islands to climate change", *WIREs Climate Change*, Vol. 8/6, http://dx.doi.org/10.1002/wcc.478. [75]

Elhadi, Y., D. Nyariki and O. Wasonga (2015), "Role of camel milk in pastoral livelihoods in Kenya: contribution to household diet and income", *Pastoralism*, Vol. 5/1, http://dx.doi.org/10.1186/s13570-015-0028-7. [141]

Eriksen, S. et al. (2021), "Adaptation interventions and their effect on vulnerability in developing countries: Help, hindrance or irrelevance?", *World Development*, Vol. 141, p. 105383, http://dx.doi.org/10.1016/j.worlddev.2020.105383. [120]

Evans, B., D. Rowell and F. Semazzi (2020), "The future-climate, current-policy framework: Towards an approach linking climate science to sector policy development", *Environmental Research Letters*, Vol. 15/11, p. 114037, http://dx.doi.org/10.1088/1748-9326/abbeb9. [43]

Falkland, T. and I. White (2020), "Freshwater availability under climate change", in *Springer Climate, Climate Change and Impacts in the Pacific*, Springer International Publishing, Cham, http://dx.doi.org/10.1007/978-3-030-32878-8_11. [223]

FAO (2021), *The Impact of Disasters and Crises on Agriculture and Food Security: 2021*, Food and Agriculture Organization of the United Nations, Rome, http://dx.doi.org/10.4060/cb3673en. [7]

Fedele, G. et al. (2019), "Transformative adaptation to climate change for sustainable social-ecological systems", *Environmental Science & Policy*, Vol. 101, pp. 116-125, http://dx.doi.org/10.1016/j.envsci.2019.07.001. [58]

Fenton, N. and M. Neil (2012), *Risk Assessment and Decision Analysis with Bayesian Networks*, CRC Press. [53]

Ferdous, M. et al. (2020), "The interplay between structural flood protection, population density, and flood mortality along the Jamuna River, Bangladesh", *Regional Environmental Change*, Vol. 20/1, http://dx.doi.org/10.1007/s10113-020-01600-1. [97]

Ferrario, F. et al. (2014), "The effectiveness of coral reefs for coastal hazard risk reduction and adaptation", *Nature Communications*, Vol. 5/1, http://dx.doi.org/10.1038/ncomms4794. [196]

Folke, C. et al. (2005), "Adaptive governance of social-ecological systems", *Annual Review of Environment and Resources*, Vol. 30/1, pp. 441-473, http://dx.doi.org/10.1146/annurev.energy.30.050504.144511. [153]

Frank, S., E. Gesick and D. Victor (2021), *Inviting Danger: How Federal Disaster, Insurance and Infrastructure Policies are Magnifying the Harm of Climate Change*, Brookings, Washington, DC, https://www.brookings.edu/wp-content/uploads/2021/03/Inviting_Danger_FINAL.pdf. [96]

Friggens, N. et al. (2020), "Tree planting in organic soils does not result in net carbon sequestration on decadal timescales", *Global Change Biology*, Vol. 26/9, pp. 5178-5188, http://dx.doi.org/10.1111/gcb.15229. [113]

FWS (2019), "The Hurricane Sandy Resilience Program: Strengthening Nature for People and Wildlife", (brochure), U.S. Fish & Wildlife Service, Washington, DC, https://www.fws.gov/hurricane/sandy/pdf/Hurricane-Sandy-Resilience-Program-fact-sheet-v4-101019.pdf. [110]

Galaz, V. et al. (2017), "Global governance dimensions of globally networked risks: The state of the art in social science research", *Risk, Hazards & Crisis in Public Policy*, Vol. 8/1, pp. 4-27, http://dx.doi.org/10.1002/rhc3.12108. [160]

Gaupp, F. et al. (2019), "Changing risks of simultaneous global breadbasket failure", *Nature Climate Change*, Vol. 10/1, pp. 54-57, http://dx.doi.org/10.1038/s41558-019-0600-z. [11]

GCA (2019), *Adapt Now: A Global Call for Leadership on Climate Resilience*, Global Commission on Adaptation, Rotterdam, https://cdn.gca.org/assets/2019-09/GlobalCommission_Report_FINAL.pdf. [102]

Girardin, C. et al. (2021), "Nature-based solutions can help cool the planet — if we act now", *Nature*, Vol. 593/7858, pp. 191-194, http://dx.doi.org/10.1038/d41586-021-01241-2. [112]

Goss, M. et al. (2020), "Climate change is increasing the likelihood of extreme autumn wildfire conditions across California", *Environmental Research Letters*, Vol. 15/9, p. 094016, http://dx.doi.org/10.1088/1748-9326/ab83a7. [20]

Government of Bangladesh (2018), *Bangladesh Delta Plan 2100*, General Economic Division, Bangladesh Planning Commission, Dhaka, http://www.plancomm.gov.bd/site/files/fd6c54f6-dfab-4c71-b44a-e983ffd2bdee/-. [35]

Government of the Netherlands (2020), *National Delta Programme 2021: Staying on Track in Climate-proofing the Netherlands*, Ministry of Infrastructure and Water Management; Ministry of Agriculture, Nature and Food Quality; Ministry of the Interior and Kingdom Relations, The Hague, https://english.deltaprogramma.nl/. [34]

Griscom, B. et al. (2017), “Natural climate solutions”, *Proceedings of the National Academy of Sciences*, Vol. 114/44, pp. 11645-11650, http://dx.doi.org/10.1073/pnas.1710465114. [111]

Gussmann, G. and J. Hinkel (2021), “A framework for assessing the potential effectiveness of adaptation policies: Coastal risks and sea-level rise in the Maldives”, *Environmental Science & Policy*, Vol. 115, pp. 35-42, http://dx.doi.org/10.1016/j.envsci.2020.09.028. [192]

Gussmann, G. and J. Hinkel (2020), “What drives relocation policies in the Maldives?”, *Climatic Change*, Vol. 163/2, pp. 931-951, http://dx.doi.org/10.1007/s10584-020-02919-8. [187]

Haasnoot, M. et al. (2020), “Defining the solution space to accelerate climate change adaptation”, *Regional Environmental Change*, Vol. 20/2, http://dx.doi.org/10.1007/s10113-020-01623-8. [33]

Haasnoot, M. et al. (2020), “Adaptation to uncertain sea-level rise; how uncertainty in Antarctic mass-loss impacts the coastal adaptation strategy of the Netherlands”, *Environmental Research Letters*, Vol. 15/3, p. 034007, http://dx.doi.org/10.1088/1748-9326/ab666c. [214]

Haasnoot, M. et al. (2013), “Dynamic adaptive policy pathways: A method for crafting robust decisions for a deeply uncertain world”, *Global Environmental Change*, Vol. 23/2, pp. 485-498, http://dx.doi.org/10.1016/j.gloenvcha.2012.12.006. [32]

Haasnoot, M. et al. (2012), “Exploring pathways for sustainable water management in river deltas in a changing environment”, *Climatic Change*, Vol. 115/3-4, pp. 795-819, http://dx.doi.org/10.1007/s10584-012-0444-2. [218]

Hada, C., R. Shaw and A. Pokhrel (2021), “Preparation and adoption of risk sensitive land use plans in the new federal context of Nepal”, in *Integrated Research on Disaster Risks, Disaster Risk Reduction*, Springer International Publishing, Cham, http://dx.doi.org/10.1007/978-3-030-55563-4_10. [117]

Hallegatte, S. (2009), “Strategies to adapt to an uncertain climate change”, *Global Environmental Change*, Vol. 19/2, pp. 240-247, http://dx.doi.org/10.1016/j.gloenvcha.2008.12.003. [209]

Hallegatte, S. et al. (2013), “Future flood losses in major coastal cities”, *Nature Climate Change*, Vol. 3/9, pp. 802-806, http://dx.doi.org/10.1038/nclimate1979. [199]

Hallegatte, S. et al. (2016), *Unbreakable: Building the Resilience of the Poor in the Face of Natural Disasters*, World Bank, Washington, DC, http://dx.doi.org/10.1596/978-1-4648-1003-9. [124]

Haque, M. et al. (2018), “Towards establishing a national mechanism to address losses and damages: A case study from Bangladesh”, in *Loss and Damage from Climate Change, Climate Risk Management, Policy and Governance*, Springer International Publishing, Cham, http://dx.doi.org/10.1007/978-3-319-72026-5_19. [81]

Harmsen, M. et al. (2019), “Taking some heat off the NDCs? The limited potential of additional short-lived climate forcers’ mitigation”, *Climatic Change*, Vol. 163/3, pp. 1443-1461, http://dx.doi.org/10.1007/s10584-019-02436-3. [62]

Hauer, M. et al. (2019), “Sea-level rise and human migration”, *Nature Reviews Earth & Environment*, Vol. 1/1, pp. 28-39, http://dx.doi.org/10.1038/s43017-019-0002-9. [130]

Headey, D. and S. Fan (2008), “Anatomy of a crisis: The causes and consequences of surging food prices”, *Agricultural Economics*, Vol. 39, pp. 375-391, http://dx.doi.org/10.1111/j.1574-0862.2008.00345.x. [16]

Healy, A. and N. Malhotra (2009), “Myopic voters and natural disaster policy”, *American Political Science Review*, Vol. 103/3, pp. 387-406, http://dx.doi.org/10.1017/s0003055409990104. [44]

Henkel, K., J. Dovidio and S. Gaertner (2006), “Institutional discrimination, individual racism, and Hurricane Katrina”, *Analyses of Social Issues and Public Policy*, Vol. 6/1, pp. 99-124, http://dx.doi.org/10.1111/j.1530-2415.2006.00106.x. [133]

Hinkel, J. et al. (2018), “The ability of societies to adapt to twenty-first-century sea-level rise”, *Nature Climate Change*, Vol. 8/7, pp. 570-578, http://dx.doi.org/10.1038/s41558-018-0176-z. [222]

Hinkel, J. et al. (2019), “Meeting user needs for sea level rise Information: A decision analysis perspective”, *Earth’s Future*, Vol. 7/3, pp. 320-337, http://dx.doi.org/10.1029/2018ef001071. [210]

Hinkel, J. et al. (2014), “Coastal flood damage and adaptation costs under 21st century sea-level rise”, *Proceedings of the National Academy of Sciences*, Vol. 111/9, pp. 3292-3297, http://dx.doi.org/10.1073/pnas.1222469111. [78]

Hino, M., C. Field and K. Mach (2017), “Managed retreat as a response to natural hazard risk”, *Nature Climate Change*, Vol. 7/5, pp. 364-370, http://dx.doi.org/10.1038/nclimate3252. [185]

Hock, R. et al. (2019), “High mountain areas”, in Pörtner, H. et al. (eds.), *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate*, Intergovernmental Panel on Climate Change, Geneva. [17]

Holdaway, A., M. Ford and S. Owen (2021), “Global-scale changes in the area of atoll islands during the 21st century”, *Anthropocene*, Vol. 33, p. 100282, http://dx.doi.org/10.1016/j.ancene.2021.100282. [181]

IDMC (2021), *The Global Report on Internal Displacement (GRID) 2021*, Internal Displacement Monitoring Centre, Geneva. [87]

IEA (2021), *Net Zero by 2050*, IEA, Paris, https://www.iea.org/reports/net-zero-by-2050. [67]

ILO (2017), *Indigenous Peoples and Climate Change: From Victims to Change Agents through Decent Work*, International Labour Organization, Geneva, https://www.ilo.org/wcmsp5/groups/public/---dgreports/---gender/documents/publication/wcms_551189.pdf. [136]

IPCC (2019), *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate*, Intergovernmental Panel on Climate Change, Geneva, https://www.ipcc.ch/srocc/. [73]

IPCC (2018), *Special Report: Global Warming of 1.5°C*, Intergovernmental Panel on Climate Change, Geneva, https://www.ipcc.ch/sr15/. [60]

IPCC (2014), *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, United Kingdom, and New York, NY. [4]

IPCC (2012), *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, United Kingdom, https://www.ipcc.ch/pdf/special-reports/srex/SREX_Full_Report.pdf. [74]

IRGC (2017), *Introduction to the IRGC Risk Governance Framework, revised version*, EPFL International Risk Governance Center, Lausanne, http://dx.doi.org/10.5075/epfl-irgc-233739. [154]

Islam, S., C. Chu and J. Smart (2020), "Challenges in integrating disaster risk reduction and climate change adaptation: Exploring the Bangladesh case", *International Journal of Disaster Risk Reduction*, Vol. 47, p. 101540, http://dx.doi.org/10.1016/j.ijdrr.2020.101540. [95]

Jack, C. et al. (2021), "Climate information: Towards transparent distillation", in *Climate Risk in Africa*, Springer International Publishing, Cham, http://dx.doi.org/10.1007/978-3-030-61160-6_2. [45]

Janetos, A. et al. (2017), *The Risk of Multiple Breadbasket Failures in the 21st Century: A Science Research Agenda*, The Frederick S. Pardee Center for the Study of the Longer-Range Future, Boston University, https://www.bu.edu/pardee/files/2017/03/Multiple-Breadbasket-Failures-Pardee-Report.pdf. [15]

Jeudy-Hugo, S., L. Lo Re and C. Falduto (2021), *Understanding countries' net-zero emissions targets*, OECD/IEA Climate Change Expert Group Papers, OECD Publishing, Paris. [63]

Jones, B. et al. (2018), "Avoiding population exposure to heat-related extremes: Demographic change vs climate change", *Climatic Change*, Vol. 146/3-4, pp. 423-437, http://dx.doi.org/10.1007/s10584-017-2133-7. [80]

Jordan, R. et al. (2015), "Citizen science as a distinct field of inquiry", *BioScience*, Vol. 65/2, pp. 208-211, http://dx.doi.org/10.1093/biosci/biu217. [149]

Kelman, I. (2015), "Difficult decisions: Migration from Small Island Developing States under climate change", *Earth's Future*, Vol. 3/4, pp. 133-142, http://dx.doi.org/10.1002/2014ef000278. [188]

Khan, M. et al. (2021), "High-density population and displacement in Bangladesh", *Science*, Vol. 372/6548, pp. 1290-1293, http://dx.doi.org/10.1126/science.abi6364. [90]

Klinke, A. and O. Renn (2019), "The coming of age of risk governance", *Risk Analysis*, Vol. 41/3, pp. 544-557, http://dx.doi.org/10.1111/risa.13383. [150]

Klinke, A. and O. Renn (2012), "Adaptive and integrative governance on risk and uncertainty", *Journal of Risk Research*, Vol. 15/3, pp. 273-292, http://dx.doi.org/10.1080/13669877.2011.636838. [152]

Klöck, C. and P. Nunn (2019), "Adaptation to climate change in Small Island Developing States: A systematic literature review of academic research", *Journal of Environment & Development*, Vol. 28/2, pp. 196-218, http://dx.doi.org/10.1177/1070496519835895. [183]

Kulp, S. and B. Strauss (2019), "New elevation data triple estimates of global vulnerability to sea-level rise and coastal flooding", *Nature Communications*, Vol. 10/1, http://dx.doi.org/10.1038/s41467-019-12808-z. [131]

Kumar, S., P. Lal and A. Kumar (2021), “Influence of Super Cyclone ’Amphan’ in the Indian subcontinent amid COVID-19 pandemic”, *Remote Sensing in Earth Systems Sciences*, Vol. 4/1-2, pp. 96-103, http://dx.doi.org/10.1007/s41976-021-00048-z. [84]

Kupferberg, J. (2021), “Migration and dignity – relocation and adaptation in the face of climate change displacement in the Pacific – a human rights perspective”, *The International Journal of Human Rights*, pp. 1-26, http://dx.doi.org/10.1080/13642987.2021.1889515. [217]

Lau, W. and K. Kim (2012), “The 2010 Pakistan flood and Russian heat wave: Teleconnection of hydrometeorological extremes”, *Journal of Hydrometeorology*, Vol. 13/1, pp. 392-403, http://dx.doi.org/10.1175/jhm-d-11-016.1. [13]

Lawrence, J. and M. Haasnoot (2017), “What it took to catalyse uptake of dynamic adaptive pathways planning to address climate change uncertainty”, *Environmental Science & Policy*, Vol. 68, pp. 47-57, http://dx.doi.org/10.1016/j.envsci.2016.12.003. [48]

Leal Filho, W. et al. (2021), “Climate change adaptation on Small Island States: An assessment of limits and constraints”, *Journal of Marine Science and Engineering*, Vol. 9/6, p. 602, http://dx.doi.org/10.3390/jmse9060602. [190]

Lempert, R. (2019), “Robust Decision Making (RDM)”, in *Decision Making under Deep Uncertainty*, Springer International Publishing, Cham, http://dx.doi.org/10.1007/978-3-030-05252-2_2. [29]

Lenton, T. et al. (2019), “Climate tipping points — too risky to bet against”, *Nature*, Vol. 575/7784, pp. 592-595, http://dx.doi.org/10.1038/d41586-019-03595-0. [22]

Levin, S. et al. (2021), “Governance in the face of extreme events: Lessons from evolutionary processes for structuring interventions, and the need to go beyond”, *SSRN Electronic Journal*, http://dx.doi.org/10.2139/ssrn.3824954. [59]

Lewis, S. et al. (2019), “Restoring natural forests is the best way to remove atmospheric carbon”, *Nature*, Vol. 568/7750, pp. 25-28, http://dx.doi.org/10.1038/d41586-019-01026-8. [115]

LIFE-AR (2019), *LDC 2050 Vision: Towards a Climate-resilient Future*, LDC Initiative for Effective Adaptation and Resilience, http://www.ldc-climate.org/wp-content/uploads/2019/09/2050-Vision.pdf. [138]

Lincke, D. and J. Hinkel (2021), “Coastal Migration due to 21st Century Sea-Level Rise”, *Earth’s Future*, Vol. 9/5, http://dx.doi.org/10.1029/2020ef001965. [129]

Li, Y. et al. (2013), “Coastal wetland loss and environmental change due to rapid urban expansion in Lianyungang, Jiangsu, China”, *Regional Environmental Change*, Vol. 14/3, pp. 1175-1188, http://dx.doi.org/10.1007/s10113-013-0552-1. [198]

LSE (n.d.), “Climate Change Laws of the World”, webpage, https://climate-laws.org/ (accessed on 11 June 2021). [166]

Marchau, V. et al. (eds.) (2019), *Decision Making under Deep Uncertainty*, Springer International Publishing, Cham, http://dx.doi.org/10.1007/978-3-030-05252-2. [25]

Marris, E. (2017), “Why fake islands might be a real boon for science”, *Nature*, Vol. 550/7674, pp. 22-24, http://dx.doi.org/10.1038/550022a. [224]

Marshall, J. and R. Plumb (2008), *Atmosphere, Ocean and Climate Dynamics: An Introductory Text*, Academic Press, Cambridge, US. [6]

Martín-Antón, M. et al. (2016), "Review of coastal land reclamation situation in the world", *Journal of Coastal Research*, Vol. 75/sp1, pp. 667-671, http://dx.doi.org/10.2112/si75-133.1. [180]

Mason, D. et al. (2020), "How urbanization enhanced exposure to climate risks in the Pacific: A case study in the Republic of Palau", *Environmental Research Letters*, Vol. 15/11, p. 114007, http://dx.doi.org/10.1088/1748-9326/abb9dc. [79]

Masson-Delmotte, V. et al. (eds.) (2021), *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, United Kingdom. [3]

McLean, R. and P. Kench (2015), "Destruction or persistence of coral atoll islands in the face of 20th and 21st century sea-level rise?", *WIREs Climate Change*, Vol. 6/5, pp. 445-463, http://dx.doi.org/10.1002/wcc.350. [208]

McLeman, R. (2017), "Thresholds in climate migration", *Population and Environment*, Vol. 39/4, pp. 319-338, http://dx.doi.org/10.1007/s11111-017-0290-2. [128]

McLeman, R. et al. (2021), "Conceptual framing to link climate risk assessments and climate-migration scholarship", *Climatic Change*, Vol. 165/1-2, http://dx.doi.org/10.1007/s10584-021-03056-6. [127]

McNamara, K., R. Westoby and A. Chandra (2021), "Exploring climate-driven non-economic loss and damage in the Pacific Islands", *Current Opinion in Environmental Sustainability*, Vol. 50, pp. 1-11, http://dx.doi.org/10.1016/j.cosust.2020.07.004. [21]

MELUR-SH (2012), *Generalplan Küstenschutz des Landes Schleswig-Holstein – Fortschreibung 2012*, Ministerium für Energiewende, Landwirtschaft, Umwelt und ländliche Räume des Landes Schleswig-Holstein, Kiel, Germany. [211]

Mishra, V. (2015), "Climatic uncertainty in Himalayan water towers", *Journal of Geophysical Research: Atmospheres*, Vol. 120/7, pp. 2689-2705, http://dx.doi.org/10.1002/2014jd022650. [19]

Munir, M. (2013), "History and development of the polluter pays principle", *SSRN Electronic Journal*, http://dx.doi.org/10.2139/ssrn.2322485. [161]

Murray-Darling Basin Authority (n.d.), *Climate Variability and Change*, webpage, https://www.mdba.gov.au/basin-plan-roll-out/climate-change (accessed on 29 April 2021). [36]

Muttitt, G. et al. (2021), *Step off the Gas: International Public Finance, Natural Gas, and Clean Alternatives in the Global South*, International Institute for Sustainable Development, Winnipeg. [69]

Mycoo, M. and M. Donovan (2018), *A Blue Urban Agenda: Adapting to Climate Change in the Coastal Cities of Caribbean and Pacific Small Island Developing States*, Inter-American Development Bank, New York. [184]

Naqvi, A., F. Gaupp and S. Hochrainer-Stigler (2020), "The risk and consequences of multiple breadbasket failures: An integrated copula and multilayer agent-based modeling approach", *OR Spectrum*, Vol. 42/3, pp. 727-754, http://dx.doi.org/10.1007/s00291-020-00574-0. [8]

Nicholls, R. et al. (2007), "Coastal systems and low-lying areas", in Parry, M. et al. (eds.), *Coastal Systems and Low-Lying Areas. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, United Kingdom. [173]

Nishat, A. et al. (2013), *A Range of Approaches to Address Loss and Damage from Climate Change Impacts in Bangladesh*, BRAC University, Dhaka, https://www.weadapt.org/sites/weadapt.org/files/legacy-new/placemarks/files/5555b2dbe48b47069.pdf. [83]

NRC (n.d.), *Dune Restoration, South Seaside Park, NJ*, Case Study, Naturally Resilient Communities:, http://nrcsolutions.org/wp-content/uploads/2017/05/NRC_CaseStudies_Dune-Restoration_South-Seaside-Park_NJ.pdf. [108]

Nurse, L. et al. (2014), *Small islands, Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel of Climate Change*, Cambridge University Press, Cambridge, United Kingdom, and New York. [220]

OECD (2021), "Adapting to a changing climate in the management of coastal zones", *OECD Environment Policy Papers*, No. 24, OECD Publishing, Paris, http://dx.doi.org/10.1787/b21083c5-en. [77]

OECD (2021), *Strengthening Climate Resilience: Guidance for Governments and Development Co-operation*, OECD Publishing, Paris, https://dx.doi.org/10.1787/4b08b7be-en. [147]

OECD (2021), *Transport strategies for net-zero systems by design*, OECD Publishing, Paris. [71]

OECD (2020), *Common Ground Between the Paris Agreement and the Sendai Framework: Climate Change Adaptation and Disaster Risk Reduction*, OECD Publishing, Paris, https://dx.doi.org/10.1787/3edc8d09-en. [57]

OECD (2020), "Nature-based solutions for adapting to water-related climate risks", *OECD Environment Policy Papers*, No. 21, OECD Publishing, Paris, https://dx.doi.org/10.1787/2257873d-en. [106]

OECD (2020), *OECD Compendium of Policy Good Practices for Quality Infrastructure Investment*, OECD Publishing, Paris, https://www.oecd.org/finance/oecd-compendium-of-policy-good-practices-for-quality-infrastructure-investment.htm. [42]

OECD (2019), *Accelerating Climate Action: Refocusing Policies through a Well-being Lens*, OECD Publishing, Paris, https://dx.doi.org/10.1787/2f4c8c9a-en. [158]

OECD (2018), "Climate-resilient infrastructure", *OECD Environment Policy Papers*, No. 14, OECD Publishing, Paris, http://dx.doi.org/10.1787/4fdf9eaf-en. [41]

OECD (2018), *Making Development Co-operation Work for Small Island Developing States*, OECD Publishing, Paris, https://dx.doi.org/10.1787/9789264287648-en. [206]

OECD (2017), *Investing in Climate, Investing in Growth*, OECD Publishing, Paris, https://dx.doi.org/10.1787/9789264273528-en. [65]

OECD (2014), *Recommendation of the Council on the Governance of Critical Risks*, https://www.oecd.org/gov/risk/Critical-Risks-Recommendation.pdf. [151]

OECD/IEA (2021), *Update on recent progress in reform of inefficient fossil-fuel subsidies that encourage wasteful consumption*, https://www.oecd.org/fossil-fuels/publicationsandfurtherreading/OECD-IEA-G20-Fossil-Fuel-Subsidies-Reform-Update-2021.pdf. [68]

OECD/The World Bank/UN Environment (2018), *Financing Climate Futures*, OECD Publishing, Paris, http://dx.doi.org/10.1787/9789264308114-en. [145]

Oppenheimer, M. et al. (2019), *Sea Level Rise and Implications for Low Lying Islands, Coasts and Communities*, Oxford University Press. [132]

Otto, I. et al. (2020), "Social tipping dynamics for stabilizing Earth's climate by 2050", *Proceedings of the National Academy of Sciences*, Vol. 117/5, pp. 2354-2365, http://dx.doi.org/10.1073/pnas.1900577117. [163]

Pakulski, I. et al. (2021), *The Bangladesh Delta : A Lighthouse Case Study*, World Bank, Washington, DC, https://openknowledge.worldbank.org/bitstream/handle/10986/35066/The-Bangladesh-Delta-A-Lighthouse-Case-Study.pdf?sequence=5&isAllowed=y. [86]

Pearl, J. and D. Mackenzie (2018), *The Book of Why: The New Science of Cause and Effect*, Penguin. [52]

Pinsky, M., G. Guannel and K. Arkema (2013), "Quantifying wave attenuation to inform coastal habitat conservation", *Ecosphere*, Vol. 4/8, p. art95, http://dx.doi.org/10.1890/es13-00080.1. [194]

Pontee, N. et al. (2016), "Nature-based solutions: Lessons from around the world", *Proceedings of the Institution of Civil Engineers - Maritime Engineering*, Vol. 169/1, pp. 29-36, http://dx.doi.org/10.1680/jmaen.15.00027. [175]

Popper, S. (2019), "Robust decision making and scenario discovery in the absence of formal models", *Futures & Foresight Science*, Vol. 1/3-4, http://dx.doi.org/10.1002/ffo2.22. [40]

Quataert, E. et al. (2015), "The influence of coral reefs and climate change on wave-driven flooding of tropical coastlines", *Geophysical Research Letters*, Vol. 42/15, pp. 6407-6415, http://dx.doi.org/10.1002/2015gl064861. [195]

Rahaman, M. et al. (2020), "Nature-based solutions to promote climate change adaptation and disaster risk reduction along the coastal belt of Bangladesh", in *The Palgrave Handbook of Climate Resilient Societies*, Springer International Publishing, Cham, http://dx.doi.org/10.1007/978-3-030-32811-5_49-1. [85]

Ranger, N., T. Reeder and J. Lowe (2013), "Addressing 'deep' uncertainty over long-term climate in major infrastructure projects: Four innovations of the Thames Estuary 2100 Project", *EURO Journal on Decision Processes*, Vol. 1/3-4, pp. 233-262, http://dx.doi.org/10.1007/s40070-013-0014-5. [219]

Ribot, J. (2014), "Cause and response: vulnerability and climate in the Anthropocene", *The Journal of Peasant Studies*, Vol. 41/5, pp. 667-705, http://dx.doi.org/10.1080/03066150.2014.894911. [122]

Robinson, S. (2020), "Climate change adaptation in SIDS : A systematic review of the literature pre and post the IPCC Fifth Assessment Report", *WIREs Climate Change*, Vol. 11/4, http://dx.doi.org/10.1002/wcc.653. [191]

Rocha, I. et al. (2021), "Typhoons during the COVID-19 pandemic in the Philippines: Impact of a double crisis on mental health", *Disaster Medicine and Public Health Preparedness*, pp. 1-4, http://dx.doi.org/10.1017/dmp.2021.140. [2]

Rogelj, J. et al. (2021), "Net-zero emissions targets are vague: Three ways to fix", *Nature*, Vol. 591/7850, pp. 365-368, http://dx.doi.org/10.1038/d41586-021-00662-3. [66]

Rupp-Armstrong, S. and R. Nicholls (2007), "Coastal and estuarine retreat: A comparison of the application of managed realignment in England and Germany", *Journal of Coastal Research*, Vol. 23/6, http://www.jstor.org/stable/30138541. [186]

Salman, R. et al. (2019), *Transformative adaptation in livestock production systems*, World Resources Institute, Washington, DC, http://www.wri.org/publication/livestock-transformative-adaptation. [139]

Schäfer, L., K. Warner and S. Kreft (2018), "Exploring and Managing Adaptation Frontiers with Climate Risk Insurance", in *Loss and Damage from Climate Change, Climate Risk Management, Policy and Governance*, Springer International Publishing, Cham, http://dx.doi.org/10.1007/978-3-319-72026-5_13. [98]

Scheidel, A. and C. Work (2018), "Forest plantations and climate change discourses: New powers of 'green' grabbing in Cambodia", *Land Use Policy*, Vol. 77, pp. 9-18, http://dx.doi.org/10.1016/j.landusepol.2018.04.057. [114]

Schweizer, P. and O. Renn (2019), "Governance of systemic risks for disaster prevention and mitigation", *Disaster Prevention and Management: An International Journal*, Vol. 28/6, pp. 862-874, http://dx.doi.org/10.1108/dpm-09-2019-0282. [156]

Scott, C. et al. (2019), "Water in the Hindu Kush Himalaya", in *The Hindu Kush Himalaya Assessment*, Springer International Publishing, Cham, http://dx.doi.org/10.1007/978-3-319-92288-1_8. [18]

Seaman, J. et al. (2014), "The Household Economy Approach. Managing the impact of climate change on poverty and food security in developing countries", *Climate Risk Management*, Vol. 4-5, pp. 59-68, http://dx.doi.org/10.1016/j.crm.2014.10.001. [54]

Seddon, N. et al. (2020), "Understanding the value and limits of nature-based solutions to climate change and other global challenges", *Philosophical Transactions of the Royal Society B: Biological Sciences*, Vol. 375/1794, p. 20190120, http://dx.doi.org/10.1098/rstb.2019.0120. [107]

Serpa, S. (ed.) (2021), "Review on socio-economic impacts of 'Triple Threats' of COVID-19, desert locusts, and floods in East Africa: Evidence from Ethiopia", *Cogent Social Sciences*, Vol. 7/1, p. 1885122, http://dx.doi.org/10.1080/23311886.2021.1885122. [1]

Setzer, J. and R. Byrnes (2020), *Global Trends in Climate Change Litigation: 2020 Snapshot*, Grantham Research Institute on Climate Change and the Environment, London, https://www.lse.ac.uk/granthaminstitute/wp-content/uploads/2020/07/Global-trends-in-climate-change. [165]

Shakhawat Hossain, M. et al. (2020), "Climate change impacts on farmland value in Bangladesh", *Ecological Indicators*, Vol. 112, p. 106181, http://dx.doi.org/10.1016/j.ecolind.2020.106181. [82]

Shamsuddoha, M. et al. (2013), *Establishing Links between Disaster Risk Reduction and Climate Change Adaptation in the Context of Loss and Damage: Policies and Approaches to Bangladesh*, Center for Participatory Research and Development, Dhaka. [94]

Shepherd, T. (2019), "Storyline approach to the construction of regional climate change information", *Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences*, Vol. 475/2225, p. 20190013, http://dx.doi.org/10.1098/rspa.2019.0013. [38]

Shepherd, T. (2014), "Atmospheric circulation as a source of uncertainty in climate change projections", *Nature Geoscience*, Vol. 7/10, pp. 703-708, http://dx.doi.org/10.1038/ngeo2253. [28]

Shepherd, T. et al. (2018), "Storylines: An alternative approach to representing uncertainty in physical aspects of climate change", *Climatic Change*, Vol. 151/3-4, pp. 555-571, http://dx.doi.org/10.1007/s10584-018-2317-9. [39]

Shortridge, J., S. Guikema and B. Zaitchik (2016), "Robust decision making in data scarce contexts: Addressing data and model limitations for infrastructure planning under transient climate change", *Climatic Change*, Vol. 140/2, pp. 323-337, http://dx.doi.org/10.1007/s10584-016-1845-4. [31]

Shuttleworth, E. et al. (2019), "Restoration of blanket peat moorland delays stormflow from hillslopes and reduces peak discharge", *Journal of Hydrology X*, Vol. 2, p. 100006, http://dx.doi.org/10.1016/j.hydroa.2018.100006. [116]

Siders, A., M. Hino and K. Mach (2019), "The case for strategic and managed climate retreat", *Science*, Vol. 365/6455, pp. 761-763, http://dx.doi.org/10.1126/science.aax8346. [204]

Smallegan, S. et al. (2016), "Morphological response of a sandy barrier island with a buried seawall during Hurricane Sandy", *Coastal Engineering*, Vol. 110, pp. 102-110, http://dx.doi.org/10.1016/j.coastaleng.2016.01.005. [109]

Soergel, B. et al. (2021), "Combining ambitious climate policies with efforts to eradicate poverty", *Nature Communications*, Vol. 12/1, http://dx.doi.org/10.1038/s41467-021-22315-9. [72]

Somanathan, E. et al. (2014), "National and sub-national policies and institutions", in Edenhofer, O. et al. (eds.), *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, United Kingdom, and New York. [143]

Spalding, M. et al. (2013), "Coastal ecosystems: A critical element of risk reduction", *Conservation Letters*, Vol. 7/3, pp. 293-301, http://dx.doi.org/10.1111/conl.12074. [176]

Speelman, L., R. Nicholls and J. Dyke (2016), "Contemporary migration intentions in the Maldives: The role of environmental and other factors", *Sustainability Science*, Vol. 12/3, pp. 433-451, http://dx.doi.org/10.1007/s11625-016-0410-4. [207]

Storlazzi, C. et al. (2018), "Most atolls will be uninhabitable by the mid-21st century because of sea-level rise exacerbating wave-driven flooding", *Science Advances*, Vol. 4/4, p. eaap9741, http://dx.doi.org/10.1126/sciadv.aap9741. [221]

Stuart-Smith, R. et al. (2021), "Filling the evidentiary gap in climate litigation", *Nature Climate Change*, http://dx.doi.org/10.1038/s41558-021-01086-7. [170]

Sudmeier-Rieux, K. et al. (2015), "Opportunities, incentives and challenges to risk sensitive land use planning: Lessons from Nepal, Spain and Vietnam", *International Journal of Disaster Risk Reduction*, Vol. 14, pp. 205-224, http://dx.doi.org/10.1016/j.ijdrr.2014.09.009. [76]

Surminski, S. and D. Oramas-Dorta (2013), "Do flood insurance schemes in developing countries provide incentives to reduce physical risks?", *Centre for Climate Change Economics and Policy Working Paper*, Vol. 139, http://www.cccep.ac.uk/wp-content/uploads/2015/10/WP11. [99]

Temmerman, S. et al. (2013), "Ecosystem-based coastal defence in the face of global change", *Nature*, Vol. 504/7478, pp. 79-83, http://dx.doi.org/10.1038/nature12859. [177]

Thomas, A. and L. Benjamin (2018), "Policies and mechanisms to address climate-induced migration and displacement in Pacific and Caribbean small island developing states", *International Journal of Climate Change Strategies and Management*, Vol. 10/1, pp. 86-104, http://dx.doi.org/10.1108/ijccsm-03-2017-0055. [216]

Thomas, K. et al. (2018), "Explaining differential vulnerability to climate change: A social science review", *Wiley Interdisciplinary Reviews: Climate Change*, Vol. 10/2, http://dx.doi.org/10.1002/wcc.565. [119]

Tiggeloven, T. et al. (2020), "Global-scale benefit–cost analysis of coastal flood adaptation to different flood risk drivers using structural measures", *Natural Hazards and Earth System Sciences*, Vol. 20/4, pp. 1025-1044, http://dx.doi.org/10.5194/nhess-20-1025-2020. [200]

Toussaint, P. (2020), "Loss and damage and climate litigation: The case for greater interlinkage", *Review of European, Comparative & International Environmental Law*, http://dx.doi.org/10.1111/reel.12335. [167]

Trenberth, K. and J. Fasullo (2012), "Climate extremes and climate change: The Russian heat wave and other climate extremes of 2010", *Journal of Geophysical Research: Atmospheres*, Vol. 117/D17, pp. n/a-n/a, http://dx.doi.org/10.1029/2012jd018020. [14]

Tye, S. and D. Grinspan (2020), "Building a climate resilient future for Costa Rica's coffee farming communities", *Practice Note*, World Resources Institute, Washington, DC, http://dx.doi.org/10.46830/wripn.19.00103. [142]

UK Government (2021), *Thames Estuary TE2100 Plan*, https://www.gov.uk/government/publications/thames-estuary-2100-te2100/thames-estuary-2100-te2100 (accessed on 29 April 2021). [37]

UN (2020), *Flash Update # 2*, 22 May, UN Resident Coordinator for Bangladesh, https://reliefweb.int/report/bangladesh/office-un-resident-coordinator-flash-update-2-22-may-2020-bangladesh-2020-very (accessed on 8 July 2021). [89]

UN Human Rights Committee (2020), *Views adopted by the Committee under article 5 (4) of the Optional*, https://demaribus.files.wordpress.com/2020/02/2728-2016.pdf. [169]

UNDP (2019), *Five Approaches to Build Functional Early Warning Systems*, United Nations Development Programme, New York, https://reliefweb.int/report/world/five-approaches-build-functional-early-warning-systems. [105]

UNDRR (2021), *GAR Special Report on Drought*, United Nations Office for Disaster Risk Reduction, Baltimore, US. [157]

UNDRR (2019), *Global Assessment Report on Disaster Risk Reduction*, United Nations Office for Disaster Risk Reduction, Baltimore, US, https://gar.undrr.org/report-2019. [9]

UNDRR (2015), *Sendai Framework for Disaster Risk Reduction 2015 - 2030*, United Nations Office for Disaster Risk Reduction, Geneva, https://www.undrr.org/publication/sendai-framework-disaster-risk-reduction-2015-2030. [100]

UNEP (2021), *Global Climate Litigation Report: 2020 Status Review*, UN Environment Programme, Nairobi, https://www.unep.org/resources/report/global-climate-litigation-report-2020-status-review. [168]

UNFCCC (2020), *Policy Brief: Technologies for Averting, Minimizing and Addressing Loss and Damage in Coastal Zones*, United Nations Framework Convention on Climate Change, Bonn, https://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/2020_coastalzones/cfecc85aaa8d43d38cd0f6ceae2b61e4/2bb696550804403fa08df8a924922c2e.pdf. [103]

UNFCCC (2015), *Paris Agreement*, United Nations Framework Convention on Climate Change, Bonn, https://treaties.un.org/pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XXVII-7-d&chapter=27. [61]

UNFCCC (n.d.), “Local Communities and Indigenous Peoples Platform”, webpage, https://unfccc.int/LCIPP#eq-1 (accessed on 23 June 2021). [137]

Vincent, K. and D. Conway (2021), “Key issues and progress in understanding climate risk in Africa”, in *Climate Risk in Africa*, Springer International Publishing, Cham, http://dx.doi.org/10.1007/978-3-030-61160-6_1. [24]

Vincent, K. et al. (2021), “Co-production: Learning from Contexts”, in *Climate Risk in Africa*, Springer International Publishing, Cham, http://dx.doi.org/10.1007/978-3-030-61160-6_3. [46]

Volpato, G. and E. King (2018), “From cattle to camels: Trajectories of livelihood adaptation and social-ecological resilience in a Kenyan pastoralist community”, *Regional Environmental Change*, Vol. 19/3, pp. 849-865, http://dx.doi.org/10.1007/s10113-018-1438-z. [140]

Wainwright, C. et al. (2019), “‘Eastern African Paradox’ rainfall decline due to shorter not less intense Long Rains”, *npj Climate and Atmospheric Science*, Vol. 2/1, http://dx.doi.org/10.1038/s41612-019-0091-7. [49]

Walker, W., M. Haasnoot and J. Kwakkel (2013), “Adapt or perish: A review of planning approaches for adaptation under deep uncertainty”, *Sustainability*, Vol. 5/3, pp. 955-979, http://dx.doi.org/10.3390/su5030955. [212]

Walker, W., R. Lempert and J. Kwakkel (2013), “Deep uncertainty”, in *Encyclopedia of Operations Research and Management Science*, Springer US, Boston, MA, http://dx.doi.org/10.1007/978-1-4419-1153-7_1140. [26]

Walker, W., S. Rahman and J. Cave (2001), “Adaptive policies, policy analysis, and policy-making”, *European Journal of Operational Research*, Vol. 128/2, pp. 282-289, http://dx.doi.org/10.1016/s0377-2217(00)00071-0. [213]

Webster, P. (2008), “Myanmar’s deadly daffodil”, *Nature Geoscience*, Vol. 1/8, pp. 488-490, http://dx.doi.org/10.1038/ngeo257. [104]

Webster, P., V. Toma and H. Kim (2011), “Were the 2010 Pakistan floods predictable?”, *Geophysical Research Letters*, Vol. 38/4, pp. n/a-n/a, http://dx.doi.org/10.1029/2010gl046346. [27]

White, I. and J. Lawrence (2020), “Continuity and change in national riskscapes: A New Zealand perspective on the challenges for climate governance theory and practice”, *Cambridge Journal of Regions, Economy and Society*, Vol. 13/2, pp. 215-231, http://dx.doi.org/10.1093/cjres/rsaa005. [144]

Winsemius, H. et al. (2015), *Disaster Risk, Climate Change, and Poverty: Assessing the Global Exposure of Poor People to Floods and Droughts*, World Bank, Washington, DC, http://dx.doi.org/10.1596/1813-9450-7480. [121]

WMO (2021), *State of the Global Climate 2020*, World Meteorological Organization, Geneva, https://library.wmo.int/index.php?lvl=notice_display&id=21880#.YNxd8ugzbQC. [88]

WMO (2020), *2020 State of Climate Service: Risk Information and Early Warning Systems*, World Meteorological Organization, Geneva, https://library.wmo.int/index.php?lvl=notice_display&id=21777#.YCmtXGhKg2y. [101]

Woetzel, J. et al. (2020), *Climate Risk and Response: Physical Hazards and Socioeconomic Impacts*, McKinsey Global Institute, https://www.mckinsey.com/business-functions/sustainability/our-insights/climate-risk-and-response-physical-hazards-and-socioeconomic-impacts. [118]

Woetzel, J. et al. (2020), “Will the world’s breadbaskets become less reliable?”, 18 May, McKinsey Global Institute, https://www.mckinsey.com/business-functions/sustainability/our-insights/will-the-worlds-breadbaskets-become-less-reliable. [10]

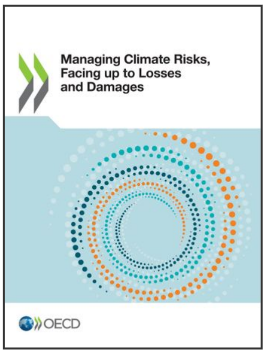
Wong, P. et al. (2014), “Coastal systems and low-lying areas”, in Field, C. et al. (eds.), *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel of Climate Change*, Cambridge University Press, Cambridge, United Kingdom, and New York. [174]

World Bank (2021), *Overlooked: Examining the Impact of Disasters and Climate Shocks on Poverty in the Europe and Central Asia Region*, World Bank, Washington, DC. [5]

Yamamoto, L. and M. Esteban (2014), *Atoll Island States and International Law*, Springer Berlin Heidelberg, Berlin, Heidelberg, http://dx.doi.org/10.1007/978-3-642-38186-7. [215]

Zheng, Z., L. Zhao and K. Oleson (2021), “Large model structural uncertainty in global projections of urban heat waves”, *Nature Communications*, Vol. 12/1, http://dx.doi.org/10.1038/s41467-021-24113-9. [23]

Zottarelli, L. (2008), “Post-Hurricane Katrina employment recovery: The Interaction of race and place”, *Social Science Quarterly*, Vol. 89/3, pp. 592-607, http://dx.doi.org/10.1111/j.1540-6237.2008.00550.x. [134]



From:
Managing Climate Risks, Facing up to Losses and Damages

Access the complete publication at:
https://doi.org/10.1787/55ea1cc9-en

Please cite this chapter as:

OECD (2021), "Policy, governance and institutions for reducing and managing losses and damages", in *Managing Climate Risks, Facing up to Losses and Damages*, OECD Publishing, Paris.

DOI: https://doi.org/10.1787/9f70f54e-en

OECD