United Nations
Climate Change

The Warsaw International Mechanism for
LOSS AND DAMAGE
Executive Committee

Technical guide on sea level rise

Acknowledgments

This technical guide was prepared under the plan of action of the Expert Group on Slow Onset Events of the Executive Committee of the Warsaw International Mechanism[1] for Loss and Damage (WIM ExCom). The technical work to develop this guide was co-led by four expert members of the group: Mr. Jaroslav Mysiak, Ms. Mariya Aleksandrova, Mr. Albert Salamanca, Mr. Akhilesh Surjan, with contribution from Ms. Elisa Calliari, member of the WIM ExCom.

The WIM ExCom extends its appreciation to the members of its thematic expert groups and a task force who provided valuable review feedback, namely the International Labour Organization, the International Organization for Migration and the Office of the United Nations High Commissioner for Refugees, as well as the WIM ExCom Champions on Slow Onset Events for their support in the preparation of this technical guide.

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All photographs are part of the “Loss and Damage in Focus: 10 Years of the Warsaw International Mechanism"
an online photo gallery of the Executive Committee of the Warsaw International Mechanism for Loss and Damage.

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1 See https://unfccc.int/topics/adaptation-and-resilience/workstreams/loss-and-damage/warsaw-international-mechanism#eq-3.

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Procedural introduction

1.1 Background

The Conference of the Parties, at its nineteenth session, established the **Warsaw International Mechanism for Loss and Damage associated with Climate Change Impacts** to address such loss and damage in developing countries that are particularly vulnerable to the adverse effects of climate change.[2] To fulfil this role under the Warsaw International Mechanism, among other things, the following functions are undertaken:[3]

- Enhancing knowledge and understanding of comprehensive risk management approaches to address loss and damage associated with the adverse effects of climate change;
- Strengthening dialogue, coordination, coherence and synergies among relevant stakeholders;
- Enhancing action and support, including finance, technology and capacity-building, to address loss and damage associated with the adverse effects of climate change to enable countries to undertake actions.[4]

The Executive Committee of the Warsaw International Mechanism, which comprises 20 representatives of Parties, guides the implementation of the Mechanism through a rolling workplan across five thematic workstreams. The Committee is assisted by five thematic expert groups established under these strategic workstreams. The thematic expert groups co-create knowledge products and undertake activities with the Committee to promote integrated and coherent approaches to averting, minimizing and addressing loss and damage associated with climate change impacts.

The **expert group on slow onset events** was launched in 2021. Under its current plan of action,[5] endorsed in 2024, it contributes to implementing the strategic workstream aimed at enhancing cooperation in relation to slow onset events at the regional and national level. At its second session, the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement mandated the Executive Committee and its thematic expert groups to develop technical guides within their work in their respective thematic area, covering:[6]

- Risk assessments, including long-term risk assessments, of climate change impacts;
- Approaches to averting, minimizing and addressing loss and damage associated with such risk assessments;
- Resources available for supporting such approaches;
- Monitoring systems for assessing the effectiveness of these approaches.

Accordingly, activities for developing thematic technical guides were incorporated into the work of the Executive Committee and the respective groups' plans of action. For slow onset events, an initial series of products will focus on glacial retreat, sea level rise and desertification. The Committee hopes that they provide information to assist developing countries in integrating relevant responses to loss and damage associated with these climate hazards into national planning and policymaking processes.

2 Decision 2/CP.19, paragraph 1.

3 Decision 2/CP.19, paragraph 5.

4 Pursuant to decision 3/CP.18, paragraph 6.

5 See the second rolling Plan of Action of the expert group on slow onset events at https://unfccc.int/sites/default/files/resource/Second_PoA_SOEs.pdf.

6 Decision 2/CMA 2, paragraph 26.

1.2 Scope

The impacts of climate change include those associated with slow onset events. Slow onset events, as initially introduced in the Cancun Agreements,[7] refer to increasing temperatures, desertification, loss of biodiversity, land and forest degradation, glacial retreat, ocean acidification, sea level rise and salinization. These hazards lead to compounded and cascading impacts, which unfold gradually and, in some cases, may result in far-reaching or irreversible loss and damage to society, culture and the environment over an extended period. These losses may differentially affect the livelihoods of people in vulnerable developing countries. The interplay between and scales of these intricate processes can add to the complexity of developing effective long-term risk management strategies for given territories or connected landscapes.

The aim of this set of technical guides is to help to establish a common understanding of how to systemically manage the impacts, and anticipate the risks, of slow onset events. It does so by giving examples of projected risks and impacts and steps that stakeholders can take to respond to these risks promptly, taking into account regional particularities, traditional knowledge and local practices.

The guides provide information on policy options, user-friendly tools and approaches for responding to these types of slow onset event in a manner that can be tailored to the needs of policymakers, governments, implementing agencies and other stakeholders at various levels. In this context, the guides also shed light on the main challenges resulting from key slow onset events for specific regional contexts and ecosystems, and showcase a wide range of examples of approaches for responding to these challenges. The approaches and solutions presented are not intended to be exhaustive. In this context, this technical guide on sea level rise starts with an introduction to the science of sea level rise and the factors that cause it (section 2). Section 3 discusses assessing the risk of sea level rise. Section 4 tackles approaches to averting, minimizing and addressing loss and damage associated with the assessed risk of sea level rise. Section 5 looks at how to fund different interventions through the various available mechanisms. Case studies are used to highlight notable examples of approaches and interventions referred to in sections 4 and 5.[8] Finally, section 6 offers suggestions on how monitoring, evaluation and learning can be facilitated to ensure that approaches are fit for repeated use.

7 Decision 1/CP.16, paragraph 25.

8 The case studies have been built based on the countries' submissions to the Transitional Committee.

2.

Technical introduction

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Sea level changes happen due to changes in the amount of ocean water, the shape of the ocean floor, shifts in Earth's gravity or rotation and the rising or sinking of land (Oppenheimer et al., 2022). As global temperatures rise, glaciers and large ice sheets on land melt, adding more water to the ocean. At the same time, as ocean temperatures increase, the water expands and takes up more space, further contributing to sea level rise. Global mean sea level change refers to the average rise or fall in ocean levels worldwide. In contrast, regional sea level changes are measured over areas of about 100 km, and local changes are measured over areas smaller than 10 km. Relative sea level change is the difference in elevation between the land and the sea at a specific place and time (Matthews et al., 2021).

Sea level rise poses substantial threats to coastal communities worldwide, including increased flooding, erosion, saltwater intrusion into freshwater resources and the loss of critical habitats (Intergovernmental Panel On Climate Change (IPCC), 2023a; IPCC, 2023b). As sea levels rise, the frequency and severity of coastal floods are expected to increase, damaging buildings, transportation networks and energy systems. This disproportionately affects vulnerable communities in low-lying coastal regions, as their limited capacity to adapt increases the risk of displacement, loss of livelihoods and health challenges. Coastal ecosystems, including wetlands, mangroves and salt marshes, are particularly vulnerable to coastal inundation and erosion. Understanding and adapting to these risks is essential for building the resilience of coastal communities. Effective adaptation strategies build on recent scientific knowledge combined with local traditional or Indigenous knowledge, community engagement and innovative solutions for addressing multifaceted challenges.

Although landward and seaward limits of the coastal zone are not consistently defined, **low-elevation coastal zones** (LECZs) are stretches of land hydrologically connected to the sea and less than 10 m above sea level (Matthews et al., 2021; McGranahan, Balk, and Anderson, 2007). Gradually developed to become home to millions of people and to host large coastal cities and critical industrial and transportation infrastructure, LECZs are among the places most vulnerable to the multiple risks caused by sea level rise. Because of their low elevation, even small increases in sea level can significantly impact them. LECZs are more likely to be affected by sea level rise owing to various geomorphological and land-use aspects, which influence how coastal risks spread and which adaptation measures may be effective.

Coastal areas, often dominated by rivers, estuaries and wetlands, have a high water table and limited drainage, making them prone to waterlogging and salinization. Vegetation includes mangroves, marshes and other coastal wetlands, which are crucial for supporting shorelines and providing habitats. Many low-lying areas are in tropical and subtropical regions with warm, humid climates. The soil in these regions is usually fertile due to river sediment deposits, supporting intensive agriculture. Coastal areas also sustain fishing industries owing to their proximity to water bodies, and attract tourism driven by recreation and nature. These regions are often densely populated, and are frequently the location of critical infrastructure such as ports, airports and urban centres.


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BOX 1: TYPOLOGIES AND ARCHETYPES OF COASTAL AREA

Recognizing that coastal areas and the people in them are diverse, adaptation strategies must take into consideration the specific vulnerabilities and requirements for effectively addressing their diverse needs. Various archetypes have been highlighted to identify their unique challenges and effective adaptation measures. Simple typologies include open coasts, deltas and estuaries, whether in rural or urban contexts (Haasnoot et al., 2019). More comprehensive typologies (Magnan et al., 2022) include urban atoll islands, Arctic communities, large tropical agricultural deltas and resource-rich cities.

- **Urban atoll islands**, such as those in Tuvalu, Kiribati and Maldives, are low-lying, ring-shaped coral islands with central lagoons. They are highly vulnerable to sea level rise, storm surges and coastal erosion. These islands face challenges like limited freshwater resources, high population densities and economies often reliant on tourism and fishing.
- **Arctic communities** in regions such as northern part of the Russian Federation, western Alaska (United States of America) and northern Canada are situated in remote, cold regions with limited accessibility. The communities rely on subsistence hunting, fishing and herding, and face challenges from thawing permafrost that leads to land subsidence and infrastructure damage, and changes in sea ice patterns that affect traditional activities.
- **Large tropical agricultural deltas**, such as the Mekong Delta in Viet Nam and the Ganges–Brahmaputra–Meghna Delta in Bangladesh and India, are fertile and densely populated regions crucial for agriculture. These deltas are highly exposed to flooding, cyclones and storm surges, with saltwater intrusion threatening agricultural productivity.
- **Resource-rich cities**, like Houston in the United States, Rotterdam in the Kingdom of the Netherlands and Shanghai in China, are economically significant hubs with large investments in infrastructure and industry, and located in coastal areas exposed to sea level rise and extreme weather events. Challenges include flooding and storm surges disrupting industrial activities and infrastructure, and urbanization leading to increased run-off and flooding.


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3.

Risk assessment of the impacts of sea level rise

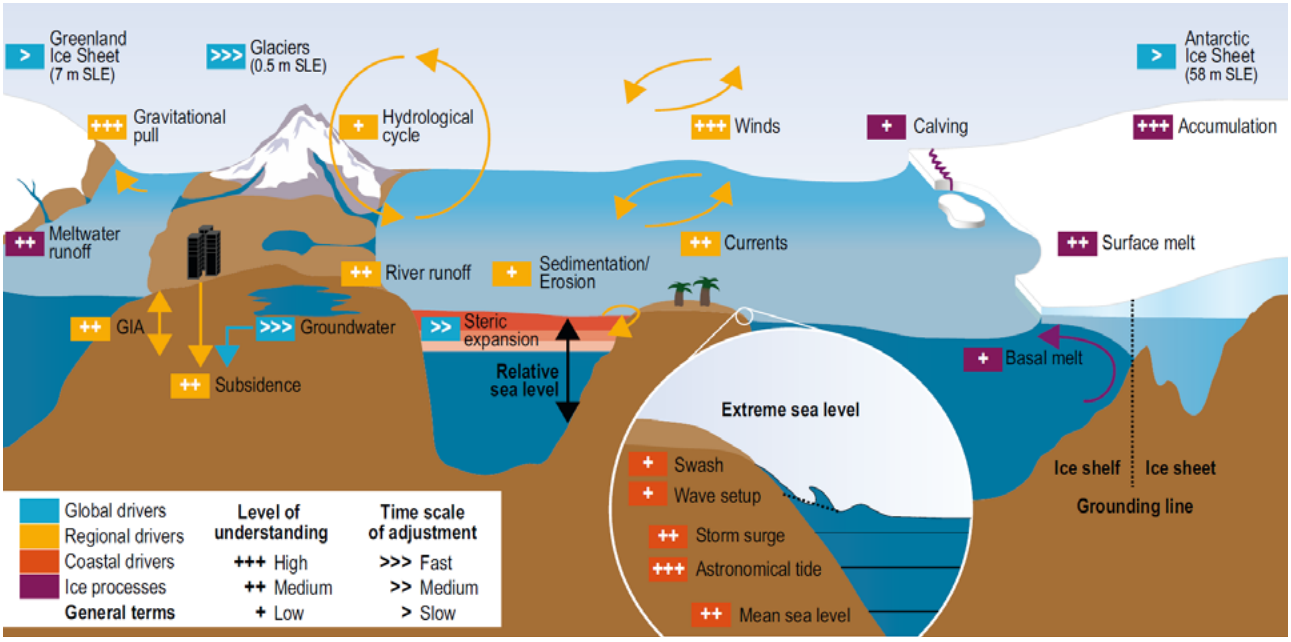
3.1 Drivers of sea level rise

Sea level rise is driven by multiple factors and has complex impacts. The melting of land ice sheets and glaciers increases the ocean's water mass and, as the ocean absorbs heat, its water warms and expands. A smaller contribution to sea level rise comes from the decrease in liquid water on land due to groundwater depletion and reduced land water retention. The redistribution of water also affects Earth's rotation and gravitational field, causing regional variations in sea level changes. Tectonics, mantle dynamics and glacial isostatic adjustment (the uplift of land previously compressed by ice sheets and subsidence in peripheral regions) also influence sea levels by causing vertical land motion and changes in sea surface height along coastlines.

Global sea level changes and local land movements influence relative sea level. Coastal areas can experience subsidence from natural sediment compaction or human activities like groundwater extraction. Hydrological cycles, including river run-off and precipitation changes, affect local sea levels by altering freshwater input into oceans. Sedimentation and erosion, affected by river damming or land-use changes, also influence coastal stability. Regionally, ocean currents and wind patterns are critical as they cause redistribution of water masses and water can pile up along coastlines, causing variations in sea levels.

Extreme sea-level events are often driven by short-term climate phenomena. Storm surges from intense storms like hurricanes and typhoons can cause significant temporary sea level rise, leading to coastal flooding. Atmospheric pressure changes, such as those during El Niño and La Niña events, can also cause sea level fluctuations. Additionally, non-climate events like tsunamis, triggered by underwater earthquakes or volcanic eruptions, can result in sudden and extreme changes in sea level.

FIGURE 1: A SCHEMATIC ILLUSTRATION OF PROCESSES INFLUENCING SEA LEVELS ALONG COASTS[9]



Source: Intergovernmental Panel on Climate Change Special Report on the Ocean and Cryosphere (SROCC) (Oppenheimer et al., 2022)

9 SLE stands for Sea Level Equivalent and GIA stands for glacio-isostatic adjustment.

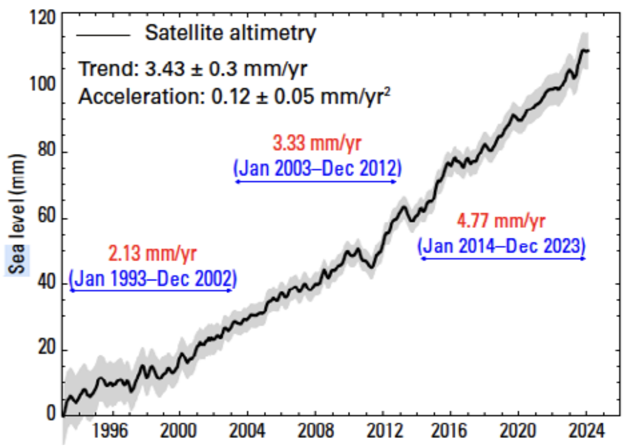
Figure 1 highlights the role of various feedback mechanisms and interactions between global, regional and local processes in influencing sea level changes along coastlines. It illustrates how both climate and non-climate factors collectively affect sea levels. For instance, ice melt and calving contribute to sea level rise, affecting ocean currents and wind patterns. Surface melt on ice sheets and the accumulation of meltwater affect ice dynamics and stability. Sedimentation processes, influenced by climate and human activities, play a crucial role in shaping coastal landscapes and their resilience to sea level changes. Understanding these interactions is essential for developing effective strategies for coastal management, resilience and adaptation to sea level changes and extreme events.

3.2 Observed and future sea level rise

Observed sea level rise has been extensively documented and updated in reports of the Intergovernmental Panel on Climate Change (IPCC) (SROCC (Oppenheimer et al., 2022) and the Sixth Assessment Report (AR6) (Intergovernmental Panel On Climate Change (IPCC), 2023a)) and in the global and regional State of the Global Climate reports (WMO, 2024) produced by the World Meteorological Organization and other regional partners, such as the Copernicus Climate Change Service. Common findings from across these reports indicate, with a high degree of certainty, that global mean sea level rose faster in the twentieth century than in any previous century over the last three millennia, and this rise has accelerated since the 1960s. The largest contributor to the observed changes is the loss of land ice, accounting for over 40 per cent of the rise in sea level, closely followed by ocean thermal expansion, which has contributed to slightly under 40 per cent. Among the ocean basins, the largest increase was recorded in the Western Pacific, while the slowest increase was observed in the Eastern Pacific (Intergovernmental Panel On Climate Change (IPCC), 2023a).

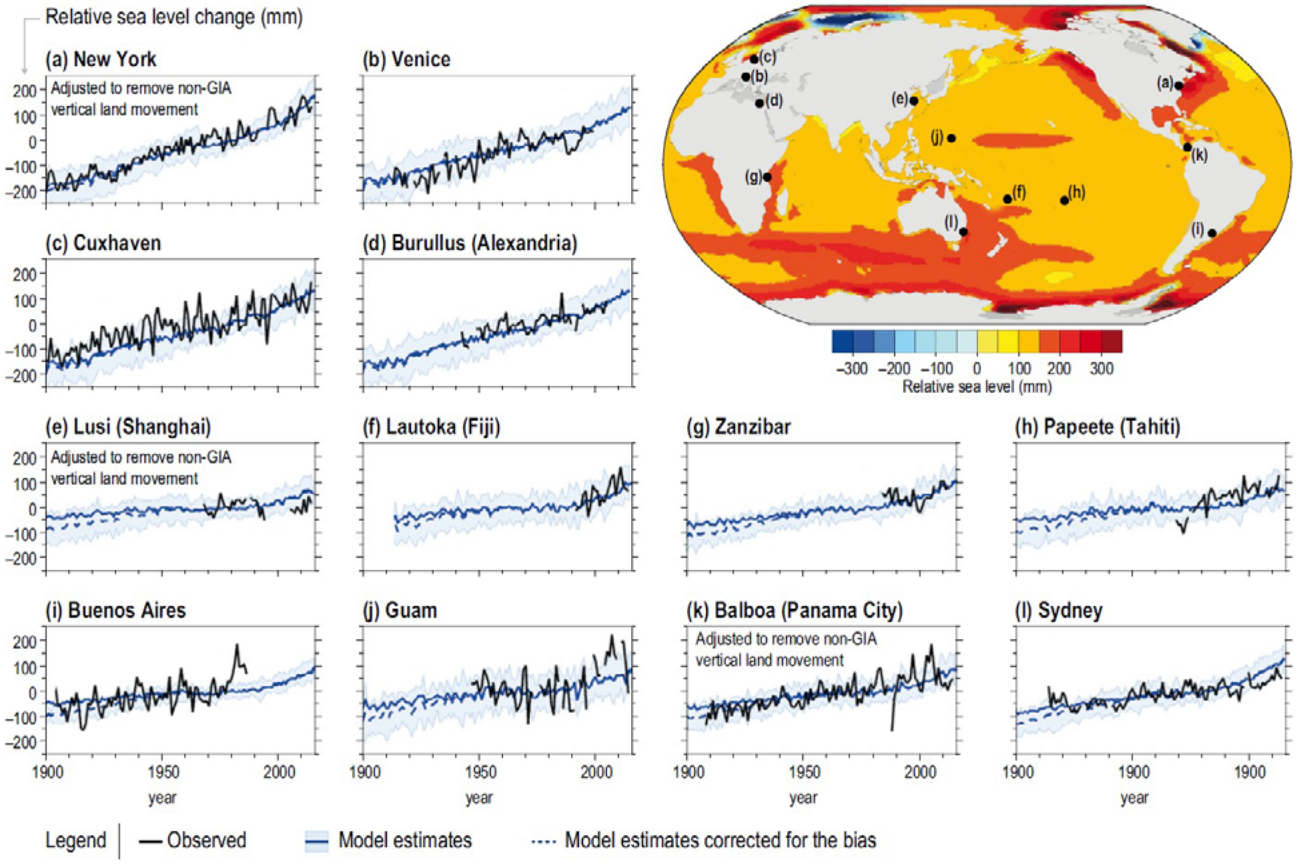
Global sea levels have risen by over 10 cm over the past 30 years and by about 21 cm since records began in 1880. According to the most recent measurements (see Figure 2), the long-term rate of sea level rise increased to 4.77 mm per year between 2014 and 2023, more than double the rate of 2.13 mm per year observed between 1993 and 2002 (WMO, 2024). Observed variations in relative sea levels show significant regional differences, influenced by land subsidence, glacial isostatic adjustment and ocean circulation patterns, leading to different areas experiencing sea level rise at different rates (see Figure 3). Global sea level rose significantly from 2022 to 2023 owing to the transition between El Niño/Southern Oscillation effects. A mild La Niña in 2021–2022 led to a lower-than-expected sea level rise, while a strong El Niño in 2023 boosted the average sea surface height.

FIGURE 2: GLOBAL MEAN SEA LEVEL EVOLUTION FROM JANUARY 1993 TO DECEMBER 2023 BASED ON SATELLITE ALTIMETRY



__Explanation:__ the black line represents the best estimate, while the grey shaded area indicates the uncertainty. World Meteorological Organization 2024 (WMO, 2024).

FIGURE 3: REGIONAL SEA LEVEL CHANGES IN THE TWENTIETH CENTURY – MODEL SIMULATIONS VERSUS TIDE GAUGE DATA[10]



Source: Chapter 4 of the SROCC, based on Oppenheimer et al., 2022.

Future projections of global sea level for mid-century are very similar across different climate scenarios. However, these projections diverge significantly over longer time scales, extending to the end of the century. This divergence is primarily due to differing projections for ice-sheet-related instability processes, which are more prone to uncertainty and are more pronounced in higher-emission scenarios. The effects of changes to components in the climate system can materialize and persist for multiple decades, or even longer. This means that, **even if the increase in global surface temperature is curbed, there is high confidence that sea level rise will continue for centuries or millennia owing to ongoing deep ocean warming and ice sheet melt, and sea levels will remain elevated for thousands of years** (IPCC, 2023b). However, rapid and sustained reductions in greenhouse gas emissions would help limit sea level rise from accelerating further and prevent the long-term trajectory of rising waters from becoming inescapable.

Compared with 1995–2014 levels, global mean sea level is projected to rise by 0.15–0.23 m by 2050 and by 0.28–0.55 m by 2100 under the low-emission SSP1-1.9[11] scenario of the IPCC. Under the high-emission SSP5-8.5 scenario, the rise is expected to be 0.20–0.29 m by 2050 and 0.63–1.01 m by 2100. Over the next 2,000 years, global mean sea level is anticipated to rise by approximately 2–3 m if warming is limited to 1.5 °C and by 2–6 m if warming is limited to 2 °C (IPCC, 2023b).

10 GIA stands for glacio-isostatic adjustment.

11 SSPs stands for Shared Socioeconomic Pathways.

The IPCC has also explored **low-likelihood, high-impact storylines** (high-end scenario) of twenty-first century sea level rise, taking into account significant sea level increases due to unpredictable processes such as the disintegration of marine ice shelves, abrupt onset of marine ice cliff instability and marine ice sheet instability in Antarctica, along with faster-than-expected ice loss in Greenland. This scenario is particularly pertinent for stakeholders planning for coastal safety and long-term infrastructure investments. Despite the uncertainty, understanding these high-end scenario risks is crucial as they could lead to sea level rise as high as 2.4 m by 2100 under the Representative Concentration Pathway RCP8.5,[12] driven by factors like ice shelf breakup, enhanced surface melt and oceanic feedback (Fox-Kemper et al., 2021). The significant uncertainties in ice sheet dynamics necessitate the consideration of extreme scenarios to avoid underestimating potential impacts and to ensure preparedness (Van De Wal et al., 2022). Incorporating high-end scenario projections helps to build robust coastal defences and sustainable urban planning to withstand future sea level rise.

3.3 Risk and impact assessments at the global level

The AR6 provides the most authoritative summary of current knowledge about the risks and impacts of climate change, including the significant challenges faced by coastal communities (Intergovernmental Panel On Climate Change (IPCC), 2023b). Recent studies published after the literature cut-off date for the AR6 continue to advance the common understanding of these issues, underscoring the ongoing need for updated and comprehensive research to inform adaptation policy and action.

Sea level rise leads to loss of land to the sea, including the ecosystems and built environments on this land. It also exacerbates other single or compound hazards, such as coastal floods due to extreme sea levels, water quality degradation and land degradation from saltwater intrusion. These hazards have a range of impacts, such as the failure of critical infrastructure systems; declined land productivity and value; damage to cultural heritage sites; loss of livelihoods; population displacement; disruption of the social fabric, leading to reduced cohesion and cultural losses; and damage to coastal ecosystems and the benefits they offer people. In some settings, sea level rise is likely to increase the risk of social conflict, such as non-violent struggles over interests, resources and influence (Oppenheimer et al., 2022).

Risks in coastal areas have been amplified by non-climate risk drivers, including population growth, demographic changes, continuous urbanization, land-use changes and resource extraction, and mitigated by the adaptation and disaster risk reduction measures that have been implemented so far. Increased population densities, together with inadequate building codes and land-use planning, have led to the development of risk-prone areas. Land reclamation and ecosystem degradation have caused loss of ecosystem services that have the potential to mitigate climate hazards (Magnan et al., 2022). Resource scarcity due to sea level rise, coastal hazards and economic instability in fragile and conflict-affected contexts require specific consideration to prevent humanitarian crises from intensifying, especially for displaced populations and their hosts.

Population and cities

An estimated 900 million people, or 12 per cent of the global population, lived in LECZs in 2020, representing an increase of over 40 per cent since 2000. More than twice as many people (2.15 billion or almost 33 per cent of the global population) live in the near-coastal zone, defined as land within 100 km of the coast at an elevation of up to 100 m. The expected annual population affected by climate change impacts could rise dramatically, from 34 million people per year in 2015 to 246 million people annually by 2100 (Reimann, Vafeidis, and Honsel, 2023). Sea level rise has the potential to compound or generate risks of statelessness or displacement of people, either within their own countries or across borders. This displacement

12 RCP stands for Representative Concentration Pathways. RCP8.5 represents a high greenhouse gas emissions scenario often considered a "business-as-usual" pathway, where there is little to no mitigation, and emissions continue to rise throughout the 21st century.

can sometimes be associated with international protection needs, triggering the application of international refugee and human rights law (UNHCR, 2023). It is important to acknowledge that not all members of populations in LECZs will be affected equally. The worst impacts will be experienced by already marginalized groups within these zones who lack the human, financial and social resources to adapt. In some cases, this leads to displacement and involuntary immobility (i.e. when people who would benefit from moving are unable to do so due to a lack of means or pathways).

Critical infrastructure

Sea level rise disrupts and destroys critical coastal infrastructure, including ports and essential nodes of marine transportation, leading to cascading effects via interconnected systems like electricity, roads and telecommunications (Martello and Whittle, 2023; Sutar, 2022; Lan et al., 2023; Durand et al., 2022; Desmet et al., 2021). This disruption can spill over into financial systems and drive financial and economic instability. The elevated groundwater levels and saltwater intrusion can corrode underground utilities and compromise structural integrity. This hidden damage affects critical infrastructure such as water supply, sewage systems and transportation networks, requiring extensive and costly repairs (Habel et al., 2024).

Ecosystems

Loss of ecosystem services and biodiversity caused by sea level rise and associated risks can lead to a loss of habitability and consequent displacement (UNFCCC, 2024). Sea level rise leads to habitat loss and forces species to migrate, reducing biodiversity and disrupting food webs and breeding grounds. The effects vary by region. Near the equator, saltwater intrusion threatens mangrove forests and local livelihoods; in temperate areas, beach erosion destroys marine breeding grounds; and in polar regions, melting sea ice displaces animal populations and disrupts food sources. Coastal ecosystems are also facing higher salinity and acidification due to climate change, leading to habitat loss and species displacement, further decreasing biodiversity and eroding coastal features (Elsey-Quirk et al., 2024; Mondal, Jose, and Roy, 2024; Osland et al., 2024; Wasim et al., 2024). Long-term loss of marine ecosystems may result in the loss of local and Indigenous traditional ecological knowledge, belief systems and ways of life. Shifts in fishing patterns threaten coastal livelihoods and can lead to a decrease in seafood consumption, causing greater economic losses for coastal communities (Esteban and Valientes, 2019).

Human health

The salinization of coastal freshwater and land resources attributed to sea level rise, along with other climate-induced drivers (like storm surges) and non-climate factors (such as water extraction and land-use changes), will continue to threaten coastal water and soil quality in the future, endangering human health (Cooley et al., 2022). In addition, impacts related to sea level rise significantly increase the risk of waterborne pathogen outbreaks in ocean and coastal regions, also affecting seafood quality and safety (Cooley et al., 2022). Relocation of marine-dependent communities, shifts in traditional diets and loss of territory and traditional roles due to sea level rise and related impacts could have profound implications for the physical and mental health of affected coastal communities (Cooley et al., 2022; Bharadwaj et al., 2023; McNamara, Westoby, and Chandra, 2021). Furthermore, today about 16 per cent of the world's population lives with significant disability (WHO, 2023). People with disabilities are at specific risk of forced displacement (UNHCR, IDMC, IDA, 2021) and greater risk of mortality and injury during disasters (Stein et al., 2024).

Loss of cultural heritage and Indigenous knowledge

Sea level rise threatens coastal archaeological and heritage sites and marine and coastal cultural ecosystem services. Long-term loss of marine ecosystems would result in irreversible loss of local knowledge, culture and well-being in some locations (Cooley et al., 2022). It is acknowledged that Indigenous Peoples adapt to the changes in their environment and, as such, are resilient to gradual climatic changes. However, should Indigenous lands and territories be lost, relocation could change the environment, affecting Indigenous Peoples' connection to the land and its resources. This may result in the Indigenous community no longer being able to practise their ways of life (be they political, social, economic or cultural) and losing their traditional and sacred grounds, all leading to the possible loss of their cultural identity. Potential decrease in seafood consumption due to food safety concerns or shifts in fishing patterns and loss of biocultural heritage could increase the risk of loss of cultural practices, especially for Indigenous Peoples (Cooley et al., 2022; McNamara, Westoby, and Chandra, 2021). Losses to cultural heritage can manifest further in diminished cultural diversity, the loss of historical patrimony for future generations and diminished cultural rights and right of access to culture (UNFCCC, 2024).

In the Pacific islands, Indigenous knowledge is critical for enhancing local adaptive capacity (Cooley et al., 2022). The Ivatans of Batanes Islands, Philippines, exemplify Indigenous Peoples' adaptive capacities, having demonstrated coping mechanisms and strategies in the face of sea level rise. Their familiarity with their coastal environment enables them to understand the ocean's currents based only on the coast's natural rhythms and appearance (Esteban and Valientes, 2019). Several authors agree that the Batanes Islands' natural environment and susceptibility to major weather challenges has led the Ivatans to cultivate local knowledge of their natural environment (Esteban and Valientes, 2019; Blolong, 1996; Shaw and Uy, 2012). The Ivatans have a traditional system of categorizing storms and warning signs to alert the community to the impending storm and give them time to prepare (Blolong, 1996). The Ivatans are known to have an "Indigenous, self-reliant, long-term cultural… approach to [their] natural hazards" (Blolong, 1996). Based on an inventory by one author, the Ivatans' Indigenous knowledge systems and practices consist of "observations of animal and human behaviours, material culture, celestial bodies and above-ground phenomena, terrestrial environment, maritime environment, and traditions and practices" (Fresnoza, 2021).

Loss of territory, social cohesion, cultural identity and cultural continuity

Land loss affects coastal and island communities' cultural, psychological and spiritual well-being. For instance, displacement, planned relocation and climate-induced migration due to the reduced habitability of low-lying coastal areas of small islands across the Pacific can result in shortages of skilled labour, loss of sense of place and social cohesion and loss of traditional adaptive mechanisms, which in turn can decrease the overall resilience and adaptative capacity of affected populations (McNamara, Westoby, and Chandra, 2021). Loss of burial sites and changes to traditional burial practices due to sea level rise and coastal inundation have been observed in small island developing States, alongside associated implications for mental well-being, social cohesion and cultural identity (Bharadwaj et al., 2023; Martyr-Koller et al., 2021). Coastal communities in particular are faced with uncertainties regarding the behaviour, natural processes and resources of the ocean, upon which many of these communities rely for their daily subsistence, well-being and cultural identity (Intergovernmental Panel On Climate Change (IPCC), 2022).

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BOX 2: PROTECTION OF PEOPLE DISPLACED ACROSS BORDERS

The effects of climate change, such as sea level rise, act as a global, systemic vulnerability multiplier. They have the potential to seriously degrade living conditions, leading to displacement and secondary movements. The widespread and profound effects of climate change act as risk multipliers for displaced people in vulnerable situations who cannot adapt to the ramifications for their safety, food and livelihood security, health, adequate housing and other basic needs and human rights. For instance, higher poverty and food insecurity rates among people with disabilities, alongside inadequate housing, tend to heighten their exposure and vulnerability to hazards, increasing the risk of being further displaced.

The adverse effects of climate change can heighten poverty levels with potential consequent impacts on the incidence of gender-based violence, including intimate partner violence, trafficking for sexual, labour or other forms of exploitation and child marriage. When women lack the resources and ability to move, they may become trapped in areas where climate and disaster risks are high. Displaced children might face specific risks related to the adverse effects of climate change. Related disasters limit their access to the basic necessities, education and healthcare facilities they require. Further, children with additional specific needs, such as those living with disabilities, unaccompanied or separated from family or other caregivers, face greater risks to their protection and need special attention.

Although not everyone displaced by climate change is a refugee, some cases where people are displaced across borders in the context of climate change and disasters will come under the definition of refugee under the 1951 Refugee Convention or regional refugee law.[13]

International human rights law also has a role to play when people displaced in the context of climate change impacts and disasters. States have an obligation to protect the human rights of all persons in their territory and subject to their jurisdiction, including individuals displaced by climate change. Furthermore, even when a person does not qualify as a refugee, they may be entitled to protection from non-refoulement if they would be subject to torture if returned to their country of origin.

In cases of large-scale influx or similar humanitarian crises, when individual status determination may not be feasible or appropriate (such as in the immediate aftermath of a disaster), should the situation in the country of origin remain unstable, temporary or humanitarian protection or stay arrangements can provide a practical tool to protect people displaced across borders. Such arrangements are not prejudiced against those without refugee status or other forms of international protection. For instance, in 2022 Argentina adopted a Special Humanitarian Visa Program for nationals and residents of the United Mexican States, Central America and the Caribbean displaced by socio-natural disasters.[14]

13 See legal considerations regarding claims for international protection made in the context of the adverse effects of climate change disasters, Office of the United Nations High Commissioner for Refugees, 2020 (link).

14 See UNHCR note on climate change, international refugee law and UNHCR's mandate, UNHCR (link).

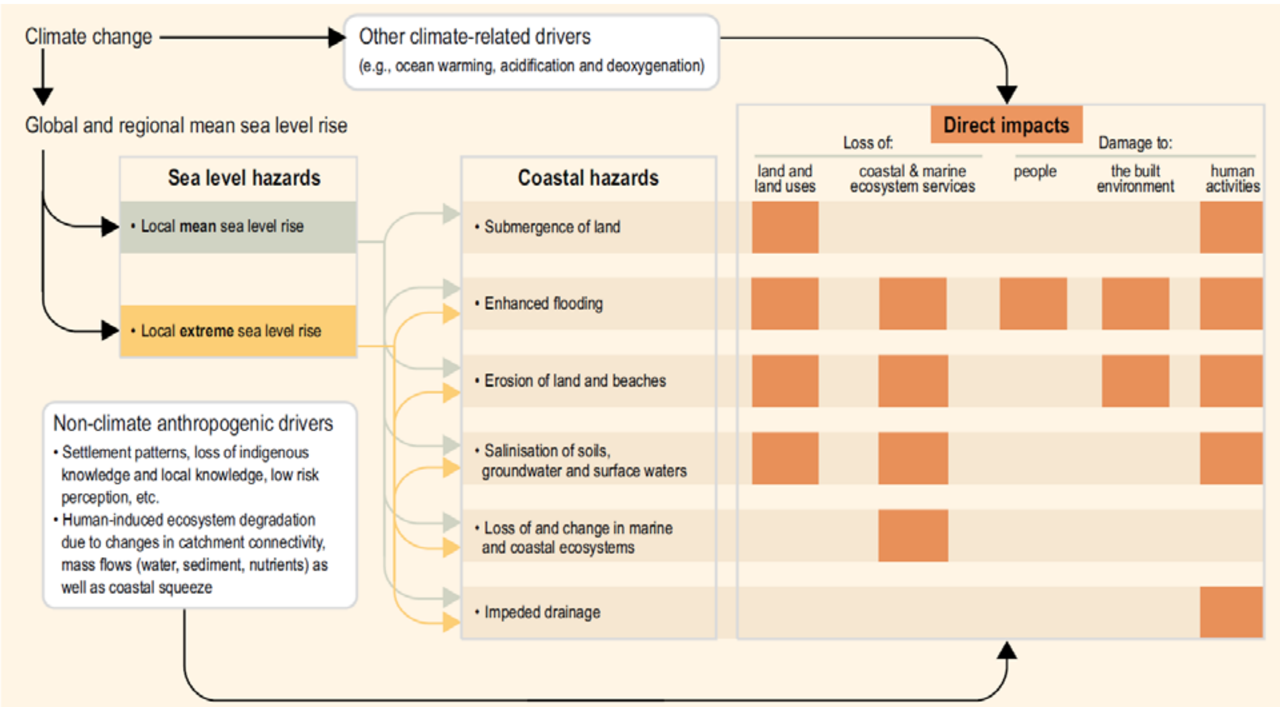
Women's well-being and security

Climate-induced coastal risks can erode women's and children's well-being through shifts in gender roles, increased risk to life, exposure to violence and gendered dependency (Ayeb-Karlsson, Chandra, and McNamara, 2023). For instance, women in Bangladesh face additional risks in cyclone scenarios due to social gender norms: such risks include the inability to swim during floods because of clothing, or being unable to relocate to shelters due to concerns about possible, alleged or actual sexual assaults (Ayeb-Karlsson, Chandra, and McNamara, 2023). In the aftermath of coastal natural disasters, women in Fiji have been exposed to the risk of violence (e.g. domestic abuse, exploitation and trafficking), while in Vanuatu, women have lost their ability to subsist on small sales at local markets. Women who have experienced coastal natural disasters often face higher rates of post-traumatic stress disorder and anxiety, and the long-term psychological impacts of these disasters are compounded by gendered caregiving responsibilities. Sea level rise poses specific health risks for pregnant women, who are particularly vulnerable in these contexts. Climate-induced coastal risks exacerbate gender inequalities (e.g. by disproportionately affecting women's land rights and increasing their dependency on male family members), creating compounded disadvantages for women in affected communities.

Cascading effects

In a world where supply chain, trade and financial interdependencies are ever-increasing, understanding the wider systemic impacts of coastal risks is important. 'Impact chains' (Zebisch et al., 2021) trace the cascading effects of the impacts of sea level rise through different sectors and potential risk storylines (van den Hurk et al., 2023). These chains give some background to the impacts of sea level rise by tracing dynamic interdependencies and feedback loops among risk drivers, highlight risk transmission pathways and help identify critical intervention points. Envisioning how a climate risk storyline might unfold takes into account how climate hazards may compound, cascade or spill over across geographic or functional boundaries, and how the interplay of risk drivers plays out in specific situations (European Environment Agency, 2024). A single initial loss can translate to multiple losses, such as loss of opportunities, habitability, security, dignity and identity, each experienced uniquely by different individuals (UNFCCC, 2024). For example, loss of cultural heritage can have cascading effects such as the breakdown of traditional governance of culture, resulting in weakened social cohesion and increased risk of conflict, in particular for Indigenous Peoples (Ayeb-Karlsson, Chandra, and McNamara, 2023).

FIGURE 4: OVERVIEW OF THE MAIN CASCADING EFFECTS OF SEA LEVEL RISE



Source: Chapter 4 of the SROCC Report, based on Oppenheimer et al., 2022.

4.

Approaches to averting, minimizing and addressing loss and damage associated with sea level rise

4.1 Introduction

A spectrum of adaptation approaches can be used to **avert, minimize and address** loss and damage. These approaches are grouped into ever-expanding categories of solutions. Each strategy involves different measures and considerations and can be applied individually or in combination, depending on the specific needs and conditions of the coastal areas. From the 1990s (Dronkers et al., 1990) to recent work, (Haasnoot et al., 2019) solutions have been organized into three categories:

- **Protect:** Defensive measures like dikes, levees, seawalls and dune-building safeguard areas from flooding and erosion. These can be improved over time to address rising sea levels. Social protection and equality are also important alongside infrastructure solutions.
- **Accommodate:** Adaptation strategies like elevating buildings, switching to salt-tolerant crops, managing groundwater and using insurance allow continued use of vulnerable areas. Institutional measures like early warning systems and social policies are crucial.
- **Retreat:** Relocation of people from high-risk areas and restricting new development is used where protection or accommodation isn't feasible, and helps to preserve coastal ecosystems. Special attention is needed for marginalized groups who are often the most affected by retreat.

TABLE 1: LIST OF THE MAIN IMPACTS OF, AND SOLUTIONS FOR, SEA LEVEL RISE

MAIN IMPACTS	MAIN TYPES OF LOSS AND DAMAGE	SOLUTIONS BY TYPE		
		Protect	**Accomodate**	**Retreat**
• Coastal inundation • Coastline erosion • Saltwater intrusion, soil and water degradation • Permanent land submergence • Human displacement • Change/loss of mangrove/ wetlands/sandy ecosystems	• Damage to buildings and infrastructure • Public health risks • Displacement, migration and statelessness • Disruption of local economies and loss of livelihoods • Damage and loss of cultural heritage and natural capital/ ecosystem services • Wider systemic risks through supply chains and interdependencies, with wide economic and social impact	• Seawalls, polders and breakwaters • Hard-engineered coastal technologies, barriers and flood gates	• Hazard-proof infrastructure • Structural elevation • Land-use zoning • Livelihood diversification • Nature-based adaptation and ecosystem restoration • Social and financial protection	• Planned relocation • Coastal retreat and resettlement

The SROCC (Intergovernmental Panel On Climate Change (IPCC), 2022) introduced an "advance" category, which involves creating new land by building into the sea to reduce coastal risks. This includes land reclamation, where fill materials raise land above sea level, and 'polderization', which uses dikes and pumping systems to manage water in low-lying areas. However, this "advance" category is not included in this guide. The SROCC also identified ecosystem-based adaptation as a distinct category, though in this guide it is included under the "accommodate" category owing to overlapping interventions.

While each of the categories – protect, accommodate and retreat – provides distinct pathways for addressing coastal risks, they are often most effective when applied in combination. Adaptation efforts tailored to the unique challenges of coastal regions should integrate elements from all three categories of solutions. For example, protective infrastructure may be complemented by accommodation measures like early warning systems, while retreat strategies can be supported by social protection policies for displaced populations. This interconnected approach creates a more comprehensive and resilient response to the complex risks posed by rising sea levels. However, as climate impacts intensify, the traditional approaches may not be enough to address the deeper, systemic vulnerabilities at play. This is where transformative adaptation policies become critical, offering a more radical shift aimed at reshaping societal structures and addressing the root causes of vulnerability and risk.

Transformative adaptation policies embrace systemic changes in response to climate risks, recognizing that detrimental global environmental change is not merely a side effect, but a characterizing trait of modern societal development (Raworth, 2017). Transformative change involves changes in social structures and power relations (Pelling, O'Brien, and Matyas, 2015), as well as the norms and institutions that shape the behaviour of people and organizations. It also involves structural reforms that reduce people's and systems' exposure to shocks (Gibson et al., 2016) while addressing the root causes of vulnerability. Transformative adaptation encompasses innovation, reorganization, expansion and reorientation (Few et al., 2017; Warner and Kuzdas, 2017). Transformative policies involve changes in existing practices, governance and market structures, for which social learning, community engagement and a deep understanding of socio-ecological impacts are prerequisites (Käyhkö et al., 2020). Implementing transformative adaptation faces institutional inertia, resource constraints and sociopolitical resistance. However, it also presents opportunities for co-benefits like improved social equity, resilience and environmental sustainability (Warner and Kuzdas, 2017). Fostering change means promoting inclusive governance, conflict-sensitive and conflict-resolution approaches, social cohesion and culturally appropriate strategies. Such change should incorporate Indigenous knowledge and local knowledge into early warning systems, sustainable resource management, social policies and planned relocation, which stand at the core transformation. However, practical guidance on inducing, designing and implementing transformative adaptation is rare.

For policymakers, an important theme running across the above-mentioned examples is equality and social justice. Who do these measures protect? Are they protecting everyone equally? Are there non-infrastructural needs (e.g. social support to help people adapt their housing)? Are they redirecting the problem towards more vulnerable communities? And how might interventions such as environmental restoration and rehabilitation and the construction of the infrastructure be managed to benefit all (we would especially focus on engaging with representatives of workers' and employers' organizations as the key implementers of these measures)?

4.2 Protect

Protective measures are aimed at defending vulnerable areas from the direct impacts of sea level rise. These strategies typically involve the construction of **physical barriers and infrastructure** to shield coastal regions from flooding and erosion. Examples include seawalls, levees, storm surge barriers and breakwaters. Natural or hybrid solutions, such as restoring or creating wetlands, mangroves and dune systems, can also buffer against storm surges and wave action. The primary goal of protective measures is to maintain the current land use and protect human activities and assets from the encroaching sea.

There are various engineering or hard infrastructure approaches to protecting coastal communities, economies and livelihoods from the impacts of sea level rise. This means several sources of insight guide how localities respond to the challenges they face. These approaches are described below. Some examples are also provided to guide their implementation. Depending on the situation and complexity of impacts, multiple lines of defence may be necessary to respond to the effects of sea level rise (Le Xuan et al., 2022).

4.2.1 Coastal armouring

Approaches to coastal armouring include seawalls, levees, breakwaters, coastal revetments, piles and groynes, and several studies have been conducted on these approaches. Many countries already have experience of using them. These structures protect coastal areas from rising tides and storm surges by absorbing and deflecting wave energy:

- **Seawalls** are vertical or near-vertical structures that absorb and reflect wave energy. Levees or dikes are embankments or raised barriers built to prevent coastal inundation and erosion. A notable example of these solutions is the Galveston Seawall in Texas (Cornwall, 2022). These approaches are, however, considered divisive due to their visual impact, impoundment or placement losses, beach access reduction, sand supply loss from eroding bluffs/cliffs and passive and active erosion (Griggs, 2010). In Maldives, building seawalls 0.5, 1.0 and 1.5 m high could delay flooding for 0.2, 0.4 and 0.6 m of sea level rise respectively. However, land raising could simultaneously reduce flood risk and address development needs.
- **Breakwaters**, either submerged or breaking the surface, are structures that manage wave impacts. The Maeslantkering in the Netherlands is an example of a breakwater and storm gate system. Bamboo is used as a breakwater in the Mekong Delta as it is readily available and cheaper (Schmitt and Albers, 2014).
- **Coastal revetments** are built perpendicular to the shoreline to trap and accumulate sediments, and prevent erosion (US Army Corps of Engineers, 2002). Between 2016 and 2020, 45.7 km of Thailand's shoreline were newly armoured by revetments (Saengsupavanich and Pranzini, 2023). Piles are also being used for coastal protection but with varying success. They transfer the load to deeper soil layers to achieve stability (Saengsupavanich et al., 2024). Piling is a common technique to achieve stability of coastal structures and is used in seawalls, bulkheads, breakwaters and the construction of piers and docks. Groynes are placed perpendicular to the shore to prevent soil movement (US Army Corps of Engineers, 2002). They feature prominently in coastal engineering management, such as on Coney Island (United States) and the Gold Coast of Australia.
- **Polder systems** combine the above approaches, notably dikes, seawalls, water storage and pumps, to protect an area from intruding seawater. However, they can only protect those areas affected by tidal floods at specific heights. They are also expensive to build and require long-term planning, lengthy construction and high maintenance costs (Murtiaji et al., 2023).

The approaches described above have environmental and biodiversity consequences on surrounding ecosystems as they "harden" shorelines (Suedel et al., 2022). As such, they should be carefully planned. Seawalls are a popular engineering response to flooding and coastal erosion due to sea level rise, especially for island coasts, but are considered maladaptive because they give a false sense of security (Nunn, Klöck, and Duvat, 2021; Nunn and Kumar, 2018). Removing shoreline armours has been shown to restore the viability of intertidal ecosystems (Des Roches et al., 2022). Thus, thoughtful consideration must be made when deciding on coastal armouring to address sea level rise. Other options suitable to the location's geographical, social and developmental context should be explored.

CASE STUDY 1: TUVALU COASTAL ADAPTATION PROJECT

Tuvalu Coastal Adaptation Project (TCAP[15]) is a comprehensive and innovative climate change adaptation intervention for one of the world's nations most at threat from sea level rise. TCAP focuses on capacity building, infrastructure protection and sustainable financing to enable Tuvalu's coastal communities to survive a changing climate. One aim of the initiative is to strengthen Tuvalu's coastal towns against rising sea levels and storm surges using USD 36 million from the Green Climate Fund[16] (GCF) and USD 2.9 million from the Government of Tuvalu, thus boosting the resilience of Tuvalu's coastal communities. Another aim is to improve Tuvalu's human resource capacity by training and transferring knowledge to professionals to qualify them to manage and implement climate change adaptation projects.

Under TCAP, storm surge and erosion susceptibility are reduced through the building and repairing of coastal infrastructure. Homes, public buildings and vital infrastructure like highways and airports will be protected from climate hazards. The aim is to integrate climate risk management into national and local planning. This means that future development projects will include climate change, making infrastructure and communities more robust. Under TCAP, sustainable financing mechanisms are being established to ensure a steady flow of resources for continuing adaptation initiatives. This will assist Tuvalu in continuing to develop its climate resilience measures and preserve and build on the accomplishments under TCAP. TCAP was launched in August 2017 and is expected to wrap up in 2024. The evaluation and impact assessment of the outcomes of the project will provide insights and examples for others on how to reduce coastal and infrastructure vulnerability through a comprehensive and sustainable approach.

Source: United Nations Development Programme (UNDP), 2023.

4.2.2 Flood barriers and gates

This approach involves constructing storm surge barriers and tidal gates in harbours and estuaries to prevent storm surges during high tides and storms, minimize flooding, particularly in low-lying areas, effectively protect harbours, reduce property damage and avoid loss of life during large storms (Chen and Orton, 2023). The opening or closing of the barriers and gates depends on the incoming water flow, including its height. Surge barriers are costly, so their utility and role in risk management should be carefully planned (Chen, Orton, and Wahl, 2020). Aside from the cost, their use should also be thoroughly vetted, particularly when applied to estuaries, as they can have several impacts, including blocking estuary-ocean exchange, stratification and salt intrusion, changing sedimentary systems and impeding animal migration and ecosystem connectivity. Their impacts are amplified with increasing gate closures. As sea levels rise, the frequency and length of gate closures will grow exponentially (Orton et al., 2023). However, prolonged closure can also affect municipal water supplies and the estuary environment due to salt intrusion and stratification (Chen and Orton, 2023). This means this solution is complicated, and its benefits should be weighed against the costs.

4.2.3 Elevating structures and land

This approach involves raising buildings or structures and introducing innovative designs that enable them to float during high water levels. This is particularly useful in flood-prone areas. In many parts of Asia, traditional houses along water bodies and in flood-prone regions were built on stilts to adapt to seasonal flooding and protect inhabitants from wild animals. However, these houses are no longer possible due to sea level rise, the wider impacts of climate change and the decline of this form of architecture. That said, there are efforts to revive them for the purpose of building resilience.

15 See https://tcap.tv/.
16 See https://www.greenclimate.fund/project/fp015.

This revival sees an adaptive form of architecture in response to the new challenges brought about by sea level rise. Latest innovations and design principles are being pursued, including the promising practice of aquatic or amphibious architecture, or "aquatecture". This consists of architecture that is shaped and informed by the aquatic environment in which it is located, and which meets some of the demands of existing in that environment. Floating and amphibious architecture is an example. Floating houses enable the structure to adjust to the vertical shifting of water levels. Existing designs are modular in structure (Stanković et al., 2021).

In Can Gio District in Ho Chi Minh City, Vietnam, elevated and floating floors were proposed so that houses became amphibious or floating to help residents cope with the impacts of sea level rise. This mechanism allows people to live with nature rather than build a hard infrastructure to fight it (Ngo et al., 2020). While still experimental, biomimetic or biologically inspired design offers ways for nature to shape a place's architecture. The giant kelp, floating water fern, Venus flower basket, red mangrove, lotus leaf, cicada and pitcher plants have been used to provide insights on addressing buoyancy, stability from lateral movement and structural integrity of floating houses (Ameh, Badarnah, and Lamond, 2024). In Maldives, island raising has been pursued as a structural adaptation intervention to address the impacts of sea level rise. This involves raising, expanding and connecting 'urban' islands, providing multiple benefits, particularly tourism and protection for residents. However, this intervention is costly and should only be pursued with a proper cost–benefit analysis.

CASE STUDY 2: COASTAL PROTECTION IN SENEGAL

Senegal's coastline, extending over 700 km, houses 60 per cent of the country's population and is a livelihood source in the form of fishing, tourism and agriculture. This includes the capital city, Dakar, situated on the Cape Verde Peninsula, the westernmost point of mainland Africa, and home to over 1 million people. The coastal system of Senegal is subject to various risks from sea level rise and coastline recession, as well as coastal erosion and increased storm surges and floods. Estuarine areas, due to their characteristics, are also exposed to other types of risk, particularly fluvial flooding (where maritime conditions influence the flow and evacuation capacities of floods) and water salinization.

To address these risks, the Senegalese Government, with international support, has implemented several coastal protection initiatives. With support from the Adaptation Fund (Palazy, 2015) the Government has constructed a 730 m coastal protection dike to shield populations and infrastructure from heavy swells and storms. The project involved rehabilitating fish processing areas, protecting a fishing wharf and constructing a 3,300 m anti-salt dike to protect rice-growing areas from saltwater intrusion. The project actively involved local communities from conception to implementation, resulting in significant community ownership and ongoing maintenance of the interventions. Another example aims to restore the beach at the Saly seaside resort in the Petite Côte region. Beach erosion had suspended activities in several hotels, significantly affecting tourism, which contributes up to 7 per cent of Senegal's gross domestic product. In partnership with the World Bank, Senegal has invested over USD 41 million to address coastal erosion and restore the beach. The project includes constructing 12 breakwaters and 7 groynes to hold back waves, restoring 7 km of beach with a width of 50 m. Furthermore, to cope with high flood losses – estimated to have cost over USD 100 million over the recent past – the Green Climate Fund financed a EUR 15 million project focusing on national flood risk mapping, detailed urban area mapping, infrastructure design tools, rainfall-runoff models, real-time hazard monitoring, groundwater knowledge improvement, optimized drainage management and enhanced warning systems. This is important as it is projected in the national adaptation plan that demographic growth and urban development may lead to increased impacts in the future.

Source: Government of Senegal, 2023

4.3 Accommodate

Accommodation strategies focus on adjusting existing green and grey infrastructure, practices, economic sectors and social systems to live with the changing conditions rather than trying to prevent the impacts of sea level rise entirely. These measures aim to reduce vulnerability, increase resilience and curb residual risk by adapting buildings, infrastructure and communities to cope with periodic flooding and other sea level rise effects. Examples include elevating buildings and infrastructure, improving drainage systems, designing flood-proof buildings and implementing zoning regulations that restrict development in high-risk areas. Accommodation measures also encompass policies and practices that promote sustainable land use and water management, ensuring that communities can thrive despite the changing environment. Other strategies that fall within this category relate to economic and social measures such as transforming food production systems, diversifying economies, adapting health systems and strengthening social protection mechanisms. For instance, in the health sector, concrete actions include investing in technology and infrastructure to improve ocean and coastal water quality monitoring and forecasting to inform planned responses; strengthening policies and institutions to plan and implement preventive public health and seafood safety measures; and raising public awareness (Cooley et al., 2022).

The following sections provide an overview of two key action areas: ecosystem-based approaches and social protection policies and measures.

4.3.1 Ecosystem-based adaptation

Ecosystems are a source of vital services, benefits and goods for people (IPBES, 2019; Pascual et al., 2017). Ecosystems can mitigate natural hazard risks and boost societal resilience, locally or regionally. The restoration of ecosystems and their services, where they have been degraded or altered, provides cost-effective solutions to sea level rise while simultaneously contributing to biodiversity protection goals. These are commonly referred to as **nature-based solutions** (NbS) (Calliari, Staccione, and Mysiak, 2019). NbS can mitigate climate risks – through mass stabilization, water flow regulation, wind dissipation and temperature regulation, remove particle pollution, improve air quality, protect soil and biodiversity and enhance climate resilience. NbS provide over one third of the cost-effective climate mitigation (Griscom et al., 2017) needed to stabilize warming to below 2 °C. The 2020 Global Standard for Nature-based Solutions (IUCN, 2020), of the International Union for Conservation of Nature, defined NbS along with criteria and indicators supporting the purposeful design, implementation, monitoring and continuous improvement of NbS interventions.[17]

The concept of NbS has been embedded in policy agreements to enhance resilience and sustainability across various global policy frameworks, recognizing the role of NbS in addressing the interconnected challenges of climate change, biodiversity loss, disaster risk and achieving the Sustainable Development Goals. The **Sharm el-Sheikh Implementation Plan**,[18] adopted by Parties to the Paris Agreement in 2022, marks the first inclusion of NbS in climate negotiations. It stressed the need to address the interconnected crises of climate change and biodiversity loss comprehensively and synergistically within the broader context of achieving the Sustainable Development Goals. NbS are also central to the Kunming-Montreal Global Biodiversity Framework, an ambitious plan to halt and reverse biodiversity loss under the **United Nations Convention on Biological Diversity**. NbS are integral to the Kunming-Montreal Global Biodiversity Framework's targets, promoting the sustainable use and management of ecosystems to enhance resilience and connectivity, restore degraded areas and support biodiversity conservation. In the context of the United Nations **Sendai Framework for Disaster Risk Reduction** 2015–2030, NbS are pivotal for enhancing resilience and reducing disaster risk. The Framework promotes the integration of NbS into disaster

17 "Actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits". Cohen-Shacham, E., Walters, G., Janzen, C., Maginnis, S. (Eds.), 2016. Nature-based solutions to address global societal challenges. IUCN International Union for Conservation of Nature. doi.org/10.2305/IUCN.CH.2016.13.en

18 Decision 1/CP.27.

risk strategies to mitigate impacts from natural hazards, leveraging the protective functions of ecosystems such as wetlands, forests and mangroves.

NbS can also be implemented in green rooftops, green walls and the re-greening of communal spaces; within public spaces, by enhancing urban parks and forests, creating water squares, greening streets and depaving urban land; and at the level of water bodies and drainage systems, through the renaturation of streams and rainwater harvesting. NbS for coastal protection use natural processes and ecosystem services to mitigate sea level rise and coastal erosion, providing sustainable alternatives to engineered infrastructure like seawalls and breakwaters (Mehvar et al., 2018; Barbier, 2016). These include:

- **Coastal wetlands**, such as salt marshes and mangroves, which can trap sediment and build elevation (Liu, Fagherazzi, and Cui, 2021). Salt marshes in intertidal zones between land and brackish water consist of salt-tolerant plants like grasses, sedges and shrubs. They form in areas protected from high-energy waves, such as estuaries and bays, and develop in zones with fine sediment deposition, assisted by tidal flows (Zu Ermgassen et al., 2021). Mangrove forests are formed by salt-tolerant trees and shrubs in intertidal zones, stabilizing coastlines with their complex root systems. Mangroves protect coasts by reducing erosion, buffering storm surges, filtering water, supporting diverse species, serving as nurseries and acting as efficient carbon sinks (Pelckmans et al., 2023).
- **Coral and oyster reefs**, which also play a vital role in protecting shorelines. Coral reefs, formed by the accumulation of calcium carbonate skeletons from coral polyps, and oyster reefs, created by the dense aggregation of oyster shells, act as natural barriers against wave action. Acting as a physical buffer, the reefs dissipate wave energy, reduce coastal erosion and mitigate the impact of storm surges (Turay, Conteh, and Gbetuwa, 2024; Beck et al., 2022). They also enhance biodiversity, support marine life and improve water quality through their filtering capabilities.
- **Sand dunes**, formed by the accumulation of transported sand and stabilized by vegetation like grasses with deep root systems, which act as natural barriers against the forces of waves, wind and storms. Dunes absorb and dissipate wave energy, reduce the impact of storm surges and high waves and prevent erosion and damage to coastal property (Nehren et al., 2017; Almarshed et al., 2019). Sand trapping methods, such as installing sand fences and planting dune-stabilizing vegetation, enhance dunes' natural formation and maintenance (Zainuddin et al., 2024; Kreyenschulte, Vélez Pérez, and Schüttrumpf, 2023).

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CASE STUDY 3: CORAL REEF RESTORATION IN PUERTO RICO

Situated in the north-eastern Caribbean, Puerto Rico faces significant coastal risks due to its geographical location. The island is vulnerable to sea level rise, coastal erosion and an increased frequency of hurricanes. These hazards threaten its infrastructure, ecosystems and communities, particularly along the coastal regions where a large portion of the population resides. Coral reefs, which act as natural barriers to reduce wave energy and protect shorelines, have been degraded by human activities and environmental stressors, weakening their protective function.

The United States Geological Survey and the University of California, Santa Cruz, initiated a project to restore damaged coral reefs. This involved transplanting coral fragments onto degraded reefs and constructing artificial reef structures to facilitate coral growth and habitat restoration, accelerating the recovery of coral ecosystems and enhancing their resilience. Innovative techniques, such as coral nurseries where coral fragments are grown before transplantation, were employed. These nurseries allow for the cultivation of many corals, which can repopulate damaged reefs. Artificial reef structures made from eco-friendly materials were also used to provide a substrate for coral attachment and growth. The restoration efforts have shown promising results, with increased coral cover and biodiversity at restoration sites, improving coastal protection by reducing wave energy and preventing shoreline erosion. The restored reefs have also provided valuable habitats for marine life, contributing to the overall health and productivity of the coastal ecosystem.

The project received funding from government agencies, non-profit organizations and private sector partners, ensuring the availability of necessary resources for successful implementation and monitoring. This collaborative approach underscores the importance of continued financial and technical support to maintain and expand reef restoration initiatives. The reef restoration project in Puerto Rico serves as a valuable example of how targeted restoration efforts can enhance coastal resilience and protect vulnerable communities from climate change impacts.

Source: The United States Geological Survey and the University of California, Santa Cruz (Storlazzi et al., 2021).

Effectiveness

While ecosystem restoration projects can be both effective in reducing coastal risks and more cost-effective than traditional engineered solutions in many cases, their performance depends on site-specific factors such as habitat width, water depth and vegetation height relative to the water level (Narayan et al., 2016). A recent global review (Vicarelli et al., 2024) found that a majority of the analysed studies indicated that NbS have consistently proven to be cost-effective in mitigating hazards, while about 25 per cent found them cost-effective under certain conditions. Mangroves, forests and coastal ecosystems were the most frequently identified as cost-effective solutions. Studies comparing NbS with engineering-based solutions found that NbS were equally, or more, effective in hazard mitigation in most cases, with a smaller portion of studies showing they were partially more effective, but never less effective than engineering alternatives. Unlike hard infrastructure, ecosystems can adapt over time, providing sustainable and long-term disaster protection, which enhances their effectiveness in addressing climate risks (Sudmeier-Rieux et al., 2021).

Other co-benefits

Compared with engineered, built or fossil-based solutions, NbS approaches may be cost-effective and have many ecological, social and economic benefits, such as biodiversity enhancement, carbon sequestration and water filtration. Co-benefits are additional but complementary to the primary goal of an adaptation solution (Jones and Doberstein, 2022). If overlooked in performance assessments or neglected during the design and implementation phases, the true value of NbS can be significantly underestimated. Proper evaluation and consideration of all benefits is crucial to fully realizing the environmental, social and economic impacts of NbS projects (Van Coppenolle, Schwarz, and Temmerman, 2018).

Implementation challenges

There are several factors challenging the adoption of NbS, which – depending on the contexts – may include poor adaptation to given sociocultural situations, possible eco-system disservices (von Döhren and Haase, 2015), absence of supportive governance and financial instruments to stimulate implementation, low social acceptance, limited business model innovation and failure to account for the true social value of the generated benefits (Venkataramanan et al., 2020). In some cases, NbS can also further amplify, rather than reduce, urban vulnerabilities and inequalities by contributing to gentrification (Haase et al., 2017; Bockarjova et al., 2020). Gentrification refers to the displacement of low-income residents as wealthier individuals move into previously affordable neighbourhoods, often leading to increased property values, rising rents and changes in the community's cultural and social fabric, which can reduce access to services and housing for the original residents. Poorly designed NbS can violate human rights by depriving Indigenous Peoples and local communities of access to essential land and resources. There's also a risk of greenwashing, where NbS are used for marketing purposes without addressing real issues: carbon offsetting is one such example. Ensuring inclusive, transparent implementation with measurable outcomes is crucial, along with embedding human rights and social justice through active community participation and safeguarding mechanisms.

Financing

Financing NbS for coastal adaptation typically involves public, private and philanthropic sources (Calliari et al., 2022). Governments contribute through climate adaptation funds or green bonds, while private investments are encouraged via tax breaks and public–private partnerships. International organizations, such as the World Bank and the GCF, provide support through grants or low-interest loans. Financial mechanisms, such as payment for ecosystem services and blended finance, are increasingly used to align environmental benefits with economic returns. Insurance can play a key role in restoring coastal ecosystems and promoting risk reduction. Insurers can offer discounts or lower premiums for those taking steps to reduce risk through NbS. Insurance-linked investments can also fund nature-based projects like wetland and coral reef restoration, and other projects that deliver multiple benefits. Recently, insurers have introduced policies aimed at insuring the ecosystems that play a vital role in safeguarding coastal properties. These products cover the costs of restoring natural defences, such as coral reefs and mangroves, after extreme weather events (Reguero et al., 2020; Chandellier and Malacain, 2021; Kousky, 2022; Kousky and Light, 2019).

Various insurance and investment solutions have been proposed and some have become operational. The Mesoamerican Reef[19] Insurance Programme provides financial protection for coral reef ecosystems through insurance policies,[20] ensuring rapid restoration after events like tropical storms. Similarly, the Prins Hendrik Sand Dike project on Texel Island, Netherlands, enhances coastal protection with sand dunes that act as natural buffers against sea level rise and storms. This project is protected by a Construction All Risks insurance policy from Swiss Re, covering material damage and third-party liability.[21] RISCO, developed by the Global Innovation Lab for Climate Finance, is a social enterprise that invests in mangrove conservation and restoration, generating revenue from insurance companies by reducing risk exposure and selling blue carbon credits. The pilot phase, led by Conservation International in the Philippines, captures mangrove forests' risk reduction and carbon sequestration benefits, with future projects planned in Brazil, Indonesia, Malaysia and Mexico (Beck, Quast, and Pfliegner, 2019).

A survey by InsuResilience Global Partnership, a global initiative promoting climate resilience through disaster risk finance and insurance solutions, found growing awareness in the insurance industry of using NbS in risk transfer, particularly for marine and coastal ecosystems (InsuResilience Secretariat, 2022). Several challenges exist to implementing nature-based insurance and investment solutions. The InsuResilience survey highlighted a lack of standardized tools for assessing NbS benefits, with most insurers relying on pilot studies. Risk selection may lead insurers to cover only some financially valuable ecosystems, leaving others unprotected and worsening inequalities. Insurance could also create moral hazard, reducing incentives for environmental protection. Lastly, a lack of transparency in policies may cause confusion about coverage.

19 See https://marfund.org/en/.

20 See https://marfund.org/en/insuring-natural-asset/.

21 See https://www.swissre.com/dam/jcr:19ebcb33-03c6-41bb-9047-917c95116b43/nature-based-solutions-pss.pdf.

Implementing effective nature-based risk-transfer strategies requires reliable data, metrics and indicators. Swiss Re developed the Biodiversity and Ecosystem Services Index (SwissRe, 2020), which assesses and scores the state of 10 ecosystem services at a 1 km^2 resolution, including habitat intactness, pollination, air quality, climate regulation, water and soil quality, erosion control, coastal protection and food and timber production. This index supports risk assessment, underwriting and environmental policy recommendations.

4.3.2 Social protection

Social protection systems are policies and mechanisms to protect people against poverty and risks to livelihood and well-being (Loewe and Schüring, 2021). Formal social protection mechanisms include services and transfers provided to individuals and households by the state (or with state support). These can include (1) social insurance – contributory schemes that provide benefits such as pensions and disability support; (2) social transfers – non-contributory social assistance schemes such as conditional or unconditional cash transfers, family allowances and subsidies; (3) employment programmes like public work programmes and employment guarantee schemes; (4) social services such as support to refugees and migrants; (5) housing support through financial transfers or provision of low-cost or social housing; and (6) labour market policies and interventions, such as unemployment benefits and skills development programmes (Loewe and Schüring, 2021; Carter et al., 2019; OECD, 2019). Traditional and informal social protection represents vital safety-net mechanisms in locations with limited coverage from formal social protection or in contexts with strong traditional social networks. Informal social protection includes traditional solidarity, self-help and semi-formalized community-based mechanisms (Schüring and Wiebe, 2021).

Formal social protection has the potential to support multiple sustainable development outcomes in the context of climate change, including efforts to reduce vulnerability, strengthen capacity to anticipate and cope with climate-related shocks, facilitate mitigation and adaptation, buffer negative social impacts of climate policies and measures (Costella et al., 2023) and promote environmental stewardship (Norton et al., 2020).

Traditionally, social protection plays an important role in responding to disasters through preparedness, relief and recovery. Conditional and unconditional cash transfers can buffer the impacts of intensifying coastal hazards on food and income security and broader social spheres, such as access to health support and education (see Box 3 and Box 4).

BOX 3: FORMAL SOCIAL PROTECTION INSTRUMENTS THAT CAN HELP ACCOMMODATE LOSS AND DAMAGE FROM SEA LEVEL RISE AND RELATED HAZARDS (SELECTED EXAMPLES)

- Conditional and unconditional cash transfers to limit the impact of coastal hazards on income and access to health services and education;
- Social transfers for people affected by environmental policies in the fisheries sector;
- Public work programmes integrated with ecosystem-based adaptation programmes, such as mangrove forest restoration;
- Subsidized microinsurance schemes for extending the risk coverage and reaching informal workers in the fisheries sector;
- Livelihood promotion and diversification through integrated social protection programmes: extension services for fish farmers and fishers, such as training for sustainable fishing, and in-kind transfers (e.g. fishing nets); support for establishing/strengthening the capacities of fisheries-based organizations;
- Social transfers, housing support and social services for climate migrants and planned relocation;
- Social health protection programmes for risks emerging from sea level rise (e.g. psychosocial support; public awareness on health risks related to sea level rise and coastal hazards).

BOX 4: ROLE OF CONDITIONAL CASH TRANSFERS

In the aftermath of super Typhoon Haiyan, which hit the Philippines in 2013, United Nations International Children's Emergency Fund provided unconditional cash transfers to thousands of affected households for six months. An evaluation of the programme showed gains even for the short term. The cash transfers provided cash for food, medicine, housing repair, conducting income-generating activities and spending for education. Since a significant part of the cash received was spent on food, it helped reduce children's malnutrition. Because of the money provided by the programme, most of the beneficiaries recovered, partially or fully, from the onslaught of the typhoon after the six-month programme (Reyes, Albert, and Reyes, 2018).

Conditional cash transfer (CCT) programmes are social protection schemes aimed at reducing poverty and inequality while transforming people's behaviour (Aleksandrova et al., 2021). For instance, CCTs have been used to encourage preventative health behaviours and to reduce inequalities in terms of access to healthcare and education, as well as to incentivize environmental stewardship. Some CCT schemes are designed to reduce child poverty and improve child health by providing predictable and regular cash payments to low-income families that agree to carry out certain 'conditions', typically related to the health and education of their children. These conditions include sending their children for regular health check-ups, ensuring regular school attendance and improving children's nutrition (Salem et al., 2021). These programmes were first introduced in Mexico with the PROGRESA (later Oportunidades) programme and in Brazil with Bolsa Família. Today, they are implemented in many countries, including the Costa Rica, India, Indonesia, Jamaica, Philippines, and sub-Saharan Africa.

The Pantawid Pamilyang Pilipino programme is one such CCT programme aimed at reducing extreme poverty by investing in child health and education. Implemented in the Philippines, a country highly affected by flooding and other impacts of sea level rise, this programme has been used for disaster response. Despite several challenges and the need for further improvement, notable outcomes of the programme include beneficial impacts on children's education, health improvements for children and pregnant women, increased household welfare, expanded community participation, greater awareness of basic means to mitigate vulnerabilities and the strengthened grit and determination of children (Orbeta, Melad, and Araos, 2023). Some of the improvements needed in the programme include ensuring transparency and communication of the programme's eligibility requirements, making monitoring beneficiary compliance less rigid and addressing delays in receiving cash transfers (Dodd et al., 2022).

Social protection support in the aftermath of climate-induced disaster is particularly crucial for people with disabilities, women and children. Anticipatory approaches to social protection allow for delivering support before forecasted shocks by linking existing social protection mechanisms to national or local early warning systems. This enables target groups to plan and prepare for anticipated shocks and avoid negative coping strategies. For example, cash transfers can help households improve flood defences, stock food or relocate from risk zones. Social protection measures are also critical to long-term recovery and rehabilitation efforts following an extreme event. Examples include psychosocial support, cash transfers for women to recover their small businesses, or public work to rehabilitate disaster-affected coastal ecosystems.

Furthermore, social protection can potentially contribute to marine and coastal protection and restoration initiatives. For instance, social protection mechanisms can help buffer against the impacts of environmental degradation and environmental protection policies and measures (such as restricting the use of natural resources), which can result in loss of income-generating opportunities and food insecurity. In addition, social protection can support effective responses to loss and damage associated with sea level rise by delivering dual social and environmental objectives. For example, well-designed public work programmes for mangrove restoration or conditional cash transfers for fish stock conservation can help mitigate income-related risks and incentivize behavioural change.

Effectiveness and sustainability

Formal social protection coverage remains low: 32.4 per cent in lower-middle income countries and only 9.7 per cent in low-income countries (International Labour Organization, 2024). Integrating environmental objectives into social protection programmes could overburden state social protection systems, especially in countries with limited institutional and financial capacities. In addition, some social assistance programmes have been linked to negative environmental outcomes such as increased natural resource extraction and vegetation loss. Furthermore, evidence shows that social protection instruments like cash transfers alone have been more effective in buffering income shocks than reducing inequality and bringing about transformation. To that end, a careful and climate-informed programme and policy design, as well as sustained financial flows, are essential (Magnan et al., 2022). At a system level, it may be more effective and efficient to offer social protection from climate change effects universally,[22] rather than granting that protection based on individual criteria or poverty (Costella and McCord, 2023). Another important consideration relates to understanding the roles of formal and informal social protection systems and how these are interlinked (Costella and McCord, 2023; Partnerships for Social Protection, 2024). At a policy level, horizontal and vertical integration of social protection into sectoral responses to climate change (and vice versa), like in the fisheries, water, disaster risk reduction and forestry sectors, could help define the role of social protection within broader climate risk management strategies across levels of governance. Social protection interventions can be more effective at a programme level when combined with livelihood protection and development approaches such as income diversification, improved access to financing, index-based insurance and fisheries extension services. Private sector actors can complement state support by providing climate services, financial products for the poor, jobs and skills development.

Financing

Domestic sources of finance for social protection include tax revenues, social security contributions, reallocating public expenditures and debt restructuring. International public finance sources include bilateral and multilateral flows for social protection, disaster risk reduction and climate change adaptation. In addition, multilateral climate funds, such as the GCF, the Global Environment Facility (GEF), the Least Developed Countries Fund, the Special Climate Change Fund, the Adaptation Fund and Climate Investment Fund, can support social protection interventions aimed at (1) integrating climate change considerations into national social protection systems through climate services provision; improved institutional, policy and regulatory environment; and enhanced knowledge and capacities; and (2) transforming existing or developing innovative social protection mechanisms (Aleksandrova, Kuhl, and Malerba, 2024).

22 Universal social protection refers to nationally defined system of policies and programmes that provide equitable access to all people and protect them throughout their lives against poverty and risks to their livelihoods and well-being (2030 Global Partnership for Universal Social Protection). The right to social security is defined in the Universal Declaration of Human Rights.

CASE STUDY 4: SOCIAL PROTECTION INTERVENTIONS SUPPORTED BY THE GREEN CLIMATE FUND

The GCF is an operating entity of the UNFCCC Financial Mechanism. The GCF can be accessed by accredited entities (public or private international, regional and national organizations). The GCF supports climate change mitigation, adaptation and cross-cutting projects in eight areas: (1) health, food and water security; (2) livelihoods of people and communities; (3) infrastructure and built environment; (4) ecosystems and ecosystem services; (5) energy generation and access; (6) transport; (7) buildings, cities, industries and appliances; and (8) forests and land use.

In addition, the GCF has been noted as a provider of finance for loss and damage "to the extent consistent with the existing investment, results framework and funding windows and structures" (UNFCCC, 2020). Project activities funded by the GCF relevant to alleviating loss and damage include development of climate services and early warning systems, community-based disaster risk reduction, construction of climate-resilient infrastructure and promotion of NbS.

To date, the GCF has supported several projects aimed at strengthening social protection systems. Some of these address sea level rise and coastal hazards. For instance, the adaptation project FP184 Vanuatu community-based climate resilience project seeks to support community-based adaptation through, among other activities, the development of locally defined shock-responsive social protection mechanisms. The multi-country project FP215 Community Resilience Partnership Program aims to strengthen the resilience of communities in target countries (Cambodia, Indonesia, Lao People's Democratic Republic, Pakistan, Papua New Guinea, Timor-Leste and Vanuatu) through the provision of finance for climate-risk-informed social protection. Planned activities include capacity-building (e.g. developing adaptive and shock-responsive social protection systems, providing technical equipment, and training), and the exploration of options for designing innovative social protection schemes or expanding existing programmes in the future.

Other projects, though not targeting sea level rise, could further exemplify the potential of the GCF to support social protection interventions in coastal areas. The project SAP042, Building climate resilience by linking climate adaptation and social protection through decentralised planning in Mozambique, aims at mainstreaming climate risk in the national productive social action programme, among other activities. A few GCF-funded projects also invest in developing social protection instruments linked to environmental initiatives that could be replicated for coastal protection and restoration. The FP062 Poverty, Reforestation, Energy and Climate Change Project in Paraguay pilots an additional conditional transfer scheme under the existing national social protection programme, Tekoporã, to incentivize ecosystem stewardship through reforestation and forest conservation in degraded lands. Similarly, the project FP158 Ecosystem-Based Adaptation and Mitigation in Botswana's Communal Rangelands seeks to transform an existing public works programme, Ipelegeng, to support rangelands restoration and promote ecosystem-based adaptation including through adjustment of policies and regulations, a new job creation programme (public works) and skills development. Through the transformed job creation programme, the project helps to tackle unemployment and to reduce costs of reactive drought relief.

Source: Aleksandrova, Kuhl, and Malerba, 2024.

4.4 Retreat

4.4.1 Strategic relocation of communities, infrastructure and economic activities

Retreat involves relocating people, infrastructure and activities to another location to reduce exposure to climate and environmental hazards. It refers to spontaneous relocations and coordinated movements facilitated by governments and organizations at various levels. The concept of 'managed retreat' started to gain prominence during the 1980s and 1990s in the context of coastal management and in response to a growing recognition of the limitations of hard engineering solutions to address the increasing risks posed by sea level rise, coastal erosion and extreme weather events. In current scholarly debates, the terms 'planned relocation', 'resettlement' and 'managed realignment' are also used to refer to similar conceptualizations of movement. The AR6 employs the term 'planned relocation' to refer to managed retreat and resettlement (Calvin et al., 2023) and defines it as "a form of human mobility response in the face of sea level rise and related impacts" that "is typically initiated, supervised and implemented from national to local level and involves small communities and individual assets but may also involve large populations" (IPCC, 2023a). Managed retreat is often considered a last resort when the protection of socio-ecological systems is no longer viable from technical, social or economic standpoints.

Legal and policy tools for managed retreat

Managed retreats can take multiple governance forms (Hanna, White, and Glavovic, 2021) and can be voluntary or mandatory for the people involved. They may be used as a preventive measure or in response to climate and environmental hazards such as coastal erosion and sea level rise. Managed retreat can be implemented at different scales, from households to communities, to villages and cities. Managed retreat can rely on a range of tools, from property acquisitions (e.g. buyouts) to land-use planning and zoning regulations (e.g. rezoning residential land and abandonment), or a combination of approaches. Table 2 provides an overview of different legal and policy tools outlined and discussed in the Georgetown Climate Center's new Managed Retreat Toolkit,[23] developed to support decision-making around managed retreat and adaptation.

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23 See https://www.georgetownclimate.org/adaptation/toolkits/managed-retreat-toolkit/market-based-tools.html.

TABLE 2: OVERVIEW OF SELECTED POLICY TOOLS FOR MANAGED RETREAT (ADAPTED FROM THE GEORGETOWN CLIMATE CENTER'S NEW MANAGED RETREAT TOOLKIT)

PLANNING TOOLS	• Hazard mitigation plans • Coastal management plans • Climate adaptation plans • Long-term or visioning plans • Post-disaster recovery and redevelopment plans • Managed retreat or relocation-specific plans • Wetlands migration or ecosystem-specific plans
INFRASTRUCTURE	• Design modifications and asset protection • Asset relocation and realignment • Infrastructure disinvestment
ACQUISITION TOOLS	• Voluntary buyouts • Open space acquisitions • Conservation land trusts • Land swaps • Leasebacks
REGULATORY TOOLS	• Setbacks and buffers • Development permit conditions • Zoning and overlay zones
MARKET-BASED TOOLS	• Transfer of Development Rights

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Effectiveness

Managed retreat is increasingly recognized as an important tool for disaster risk reduction and climate change adaptation. Moving people away from high-risk areas permanently reduces their exposure to disasters and environmental change. It also creates opportunities for nature to reclaim space, as it can be paired with restoring coastal ecosystems. In some cases, organized relocations can also represent a positive transformation for the communities involved (Siders, Ajibade, and Casagrande, 2021), for instance, when implying a shift to livelihoods that are less likely to be affected by climate hazards (Pahl-Wostl et al., 2020). Improved outcomes require the active participation of local populations in planning and decision-making, respect for the rights of those affected, the establishment of dedicated governance structures and the availability of associated funding (Schipper et al., 2022).

Limitations

Managed retreat is a sensitive intervention due to the high social costs it can entail (United Nations High Commissioner for Refugees (UNHCR), 2016). Research on development-forced displacement and resettlement has extensively documented the impoverishment of relocated communities, including homelessness, joblessness and social disintegration (Cernea, 1997). Similarly, when implemented in response to climate change impacts, a managed retreat can lead to negative outcomes for affected households and communities (Piggott-McKellar et al., 2020; Arnall, 2019). There is increasing evidence of adverse psychosocial consequences among resettled communities, including impacts on anxiety, well-being and perceived safety (Abu et al., 2024). This has prompted adaptation research to explore how relocation planning decisions influence livelihood outcomes to prevent maladaptation (Bower et al., 2023) and to interrogate what constitutes success in the context of relocation programmes (Ajibade et al., 2022). From a financial perspective, relocation can be very expensive (Ferris and Bower, 2023). Recent examples show how it can range from USD 10,000 per person in the case of Fiji, to USD 100,000 per person in the United States (Hino, Field, and Mach, 2017).

CASE STUDY 5: PLANNED RELOCATION IN FIJI

Fiji is the first country in the world to have made planned relocation a priority, and to have developed a comprehensive national relocation policy package to address climate change-induced relocation (Government of Fiji, 2023). The initiative was motivated by the need to address the escalating impacts of climate change, particularly sea level rise, on vulnerable coastal and rural communities. Since 2018, the Fijian Government has established a comprehensive policy and legal package to guide national responses to planned relocation, including the 2018 Planned Relocation Guidelines and the 2023 Standard Operating Procedures to operationalize them.

The 2021 Climate Change Act supports these policy documents by establishing principles and procedures for the relocation of communities that are at risk, and by establishing the Climate Relocation of Communities Trust Fund, which is the world's first national trust fund dedicated to community-driven planned relocation. Financing for the programme is multifaceted, leveraging domestic funding mechanisms like the Environment and Climate Adaptation Levy and international contributions. The Levy, a policy-based taxation system, contributes 3 per cent of its revenue to the Trust Fund, which is supplemented by bilateral and multilateral funding sources. This innovative financing structure ensures that resources are available to support the comprehensive relocation needs, from technical assessments to the construction of new infrastructure, thereby safeguarding the long-term resilience and sustainability of the relocated communities.

5.

Resources available for supporting approaches

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Adaptation finance refers to funding for adaptation to the adverse effects of climate change. This includes investments in infrastructure, technology and practices to enhance resilience and reduce vulnerability to climate-related hazards like floods, drought and sea level rise. In 2009, developed countries committed to a goal of jointly mobilizing USD 100 billion per year by 2020 to support climate action in developing countries as part of broader meaningful mitigation action and transparency of implementation. In adopting the Paris Agreement, developed countries extended this goal through to 2025.

There is a need to scale up adaptation finance significantly in order to meet the goals of the Paris Agreement. Achieving this requires enhanced international cooperation, increased public and private sector investments and innovative financing mechanisms. The most recent Adaptation Gap Report (United Nations Environment Programme, 2023) estimates that adaptation costs for developing countries will be USD 215–387 billion per year this decade, a significant increase from previous editions and a cost only previously expected to be reached by 2030. Modelling suggests costs could be USD 215 billion annually, rising towards 2050, while analysis of national plans estimates that USD 387 billion will be needed annually for 2021–2030.

Finance for adaptation to climate change involves various funding sources and instruments to enhance resilience and reduce vulnerabilities. Key funding instruments include grants, concessional loans and bonds, such as green and resilience bonds, which provide capital for climate-resilient infrastructure and projects. Additionally, public–private partnerships and insurance mechanisms, like catastrophe bonds, offer financial protection against climate-related losses. Major sources include multilateral climate funds such as the GCF, the Adaptation Fund and the Global Environment Facility (Box 5).

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BOX 5: SAMPLE OF RELEVANT MULTILATERAL FINANCIAL SOURCES

Various multilateral financing sources aim to support developing countries in their climate change mitigation and adaptation efforts.

- **The Green Climate Fund**[24] is an operating entity of the UNFCCC Financial Mechanism established to support developing countries in their efforts to mitigate and adapt to climate change. It provides funding for projects and programmes that aim to reduce greenhouse gas emissions and enhance climate resilience (see also Case studies 1 and 4).
- **The Global Environment Facility**[25] (GEF) is a multilateral environmental fund that provides grants and blended finance for projects related to the transition to low-emission and climate-resilient development pathways, among other things. It was established in October 1991 and serves as an operating entity of the UNFCCC Financial Mechanism, as well as other United Nations Conventions such as the Convention on Biological Diversity and the United Nations Convention to Combat Desertification.
- **The Special Climate Change Fund**[26] was established in 2001 to finance projects related to climate change adaptation and mitigation, technology transfer and capacity-building in developing countries. Managed by the GEF, the Fund focuses on addressing specific needs not covered by the GEF. Recently, the Fund has adjusted its focus to emphasize private sector mobilization, and the unique challenges faced by small island developing States, ensuring that these critical areas receive targeted support.
- **The Least Developed Countries Fund**[27] is dedicated to addressing the special needs of the least developed countries. It aims to help these countries to adapt to climate change impacts. Together with the Special Climate Change Fund, it is managed by GEF.
- **The Adaptation Fund**,[28] established in 2001, serves the Kyoto Protocol and the Paris Agreement and finances concrete adaptation projects and programmes in developing countries vulnerable to climate change. The Fund is unique in that it was initially funded by a 2 per cent share of certified emission reductions from the clean development mechanism and is expected to also receive a share of the proceeds from the market mechanism established under Article 6, paragraph 4, of the Paris Agreement (see also Case study 2).
- **The Fund for responding to Loss and Damage**[29] is a new operating entity of the Financial Mechanism of the Convention, which also serves the Paris Agreement, with the purpose to assist developing countries that are particularly vulnerable to the adverse effects of climate change in responding to economic and non-economic loss and damage associated with the adverse effects of climate change, including extreme weather events and slow onset events.

24 See https://www.greenclimate.fund/.
25 See https://www.thegef.org/.
26 See https://unfccc.int/topics/climate-finance/resources/reports-of-the-special-climate-change-fund.
27 See https://www.thegef.org/what-we-do/topics/least-developed-countries-fund-ldcf.
28 See https://www.adaptation-fund.org/.
29 See https://unfccc.int/loss-and-damage-fund-joint-interim-secretariat.

Bilateral and multilateral development banks, including the World Bank and regional institutions like the Asian Development Bank, play significant roles in financing climate adaptation, mitigation projects and disaster risk reduction efforts globally. These banks provide financial resources through loans, grants and technical assistance to help developing countries build resilient infrastructure, implement nature-based solutions and enhance their capacity to address the impacts of climate change. They also facilitate the transfer of knowledge and technology, promote policy reforms and mobilize additional funding from private sectors and other international donors. Additionally, development banks work with national governments to align projects with global climate goals, ensuring that investments contribute to sustainable development and equitable growth.

CASE STUDY 6: CLIMATE BRIDGE FUND IN BANGLADESH

Bangladesh, situated in the delta of the Ganges, Brahmaputra and Meghna rivers, faces severe coastal risks due to its low-lying geography and extensive coastline along the Bay of Bengal. The country is highly susceptible to sea level rise, which exacerbates coastal erosion and salinity intrusion and increases the frequency and intensity of cyclones and storm surges. These hazards threaten critical infrastructure, agricultural land and freshwater resources, putting millions of people at risk. The densely populated coastal regions, such as the Sundarbans, a United Nations Educational, Scientific and Cultural Organization World Heritage site, are particularly vulnerable. Adaptation measures, including the construction of cyclone shelters, embankments and improved early warning systems, are crucial for mitigating these risks and enhancing the resilience of coastal communities in Bangladesh. Additionally, sustainable land-use planning and the restoration of mangroves play a vital role in protecting the coastline and reducing the impacts of climate change.

The Climate Bridge Fund[30] is a funding mechanism enabling locally led action on loss and damage for climate-vulnerable communities. Established by BRAC with funding from the German Government, the Fund supports adaptation activities for communities displaced, or at risk of displacement, due to climate-induced impacts. It operates under the regulation of the Government of Bangladesh, with BRAC managing the secretariat and disbursing funds to local civil society organizations following the principles of locally led adaptation. The Fund comprises two lines of funding: climate change and emergency response. Under the climate change line, EUR 10 million was invested in government treasury bonds to ensure financial sustainability, with the investment income supporting projects annually. The emergency response line received an additional EUR 10 million to implement projects in districts most affected by climate shocks and the coronavirus disease 2019 pandemic.

Despite challenges, the Fund has supported nearly 150,000 people through initiatives like climate-sensitive disease awareness, climate-resilient water, sanitation and hygiene services, and infrastructure support. The Climate Bridge Fund ensures efficient spending with 60–70 per cent of operational costs at the local level, enabling scalability and relevance to global climate financing for loss and damage. The Fund adheres to eight principles of locally led adaptation: devolving decision-making to the local level; addressing structural inequalities; providing predictable funding; investing in local capabilities; understanding climate risk; flexible programming; ensuring transparency and accountability; and promoting collaborative action and investment. This model illustrates how international climate finance can effectively support communities most affected by the climate crisis.

Source: Climate Bridge Fund, 2023.

30 See https://www.brac.net/program/climate-bridge-fund/.

6.

Monitoring systems for assessing the effectiveness of approaches

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Monitoring, evaluation and learning (MEL) are vital parts of tracking progress and assessing effectiveness, facilitating learning, adjusting strategies towards climate goals and communicating the outcomes.

The Paris Agreement, adopted in 2015, emphasizes the importance of transparency, accountability and continuous improvement through MEL mechanisms. Under the Paris Agreement, reporting on adaptation is voluntary but recent adaptation decisions reaffirm the importance of MEL and encourage countries to establish and implement MEL systems.

National adaptation plans can help countries establish MEL frameworks and indicators to track risks and effectiveness of responses. Between 2015 and July 2024, 58 developing countries, including 22 least developed countries, submitted national adaptation plans (Beauchamp et al., 2024). Over 50 per cent of them include an MEL framework and indicators, and in 75 per cent the countries commit to reporting on progress. However, implementing MEL systems involves several challenges, and less than 40 per cent of countries with a national adaptation plan monitor or evaluate its implementation (Leiter, 2021). Even with approved MEL designs, most lack systematic mechanisms for tracking progress. The presence of a national adaptation plan can misleadingly suggest that adaptation efforts are adequately managed and monitored. Europe has one of the most advanced MEL systems, and all European Union member States have developed national adaptation policies. Adaptation is integrated into sectoral policies, with monitoring and reporting mechanisms for evaluating effectiveness comprehensively (European Environment Agency, 2020). Many entities have produced guidance and tools to support MEL in the context of national adaptation planning. For example, the National Adaptation Plan Global Network prepared a toolkit (Beauchamp et al., 2024) that provides practical advice for integrating MEL into adaptation planning, detailing methodologies for assessing climate risks, implementing adaptive measures and evaluating their effectiveness, with case studies illustrating best practices. *Reporting on Progress in National Adaptation Plan Processes* (Guerdat, Masud, and Beauchamp, 2023) addresses challenges in tracking progress and offers recommendations for improving reporting mechanisms. *Integrating Learning into the National Adaptation Plan Process* (Dekens and Harvey, 2024) emphasizes the role of deliberate learning, defining it as a collective process for enhancing knowledge and behaviours related to climate adaptation, and outlines strategies for embedding learning throughout the national adaptation plan process, highlighting key enablers like institutional arrangements, leadership and stakeholder engagement.

Effective coastal adaptation MEL frameworks are crucial for assessing sea level rise related risks and the associated economic, environmental and social damages and costs. Monitoring systems should help to manage long-term coastal adaptation and to identify tipping points where approaches become ineffective. They should be used to define financial, biophysical and technical limits using tools like cost–benefit analysis (British Columbia, 2013). However, only a small fraction of the largest coastal cities have developed comprehensive adaptation plans with defined MEL frameworks, including indicators and metrics. Most of these existing indicators measure the outputs of adaptation processes rather than their impacts. These indicators are necessary to assess effectiveness. Many indicators lack detailed information, clear targets and defined monitoring time frames, leading to challenges in accurately measuring progress (Goonesekera and Olazabal, 2022). There are various examples of monitoring systems that are used to assess the effectiveness of interventions in terms of social acceptability, socioeconomic development and sustainability while considering cultural, ethical, economic and political concerns (Haasnoot et al., 2019; Magnan et al., 2022; Duvat et al., 2022). An important aspect of any MEL process is its ability to be iterative and enable learning among project implementors. This is particularly crucial when risks cascade through the systems so as to prevent impacts on one system from leading to impacts on another, or so that the interaction of changes in different systems will not cause negative impacts on another. An appropriate MEL framework that is actively implemented will help prevent maladaptation resulting from sea level rise interventions.

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