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Building Resilience With Innovation To Tackle The Climate Emergency

More frequent and intense climate change-induced natural disasters are not a future scenario – they are happening now. But, solutions are available: governments and communities can use emerging digital technologies in a spirit of collaboration to manage the threat.

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Executive Summary

Escalating Climate Disaster: A Policy Response

The human and financial costs of natural disasters driven by climate change are increasing. Governments must develop a policy response that deploys innovative digital technologies through society-wide collaborative approaches to control costs and mitigate harm.

- The number of extreme weather events, such as heatwaves, wildfires, and hurricanes, has increased in recent years. If these trends persist, extreme events could increase to 560 a year by 2030 – 1.5 a day – representing a 40% increase over 2015. In addition to human suffering, the costs are huge; in 2022, natural disasters cost governments and businesses more than $200 billion – 40% more than the annual average for the past 20 years (excluding earthquakes)[1].
- Disaster impacts disproportionately affect **low-income populations with fewer resources** and less scope for adaptation.
- Global sea levels have risen by 15-25cm since 1900, and around one billion people living in **low-lying cities** and coastal settlements are projected to be at risk from sea-level rise and other climatic hazards by mid-century[2].
- Developing nations will together require an **annual financial** commitment ranging from an estimated $215 billion to $387 billion throughout the present decade to effectively address and mitigate the impacts of global warming[3].

Climate-change-related events create food and water insecurity, displacement and migration risks, health risks, infrastructure damage, and biodiversity loss. Tackling this demands a coordinated policy response that deploys new technology for risk reduction and impact mitigation.

Data-driven and digital technologies have the potential to manage such interconnected risks; technology implementations include early-warning systems, multi-hazard platforms, Earth observation, and remote sensing. Technology tools include drones, the Internet of Things (IoT), augmented and virtual reality (AR and VR), advanced computing, and AI.

Collaborative approaches between governments, private companies, academic institutions, and communities are needed to control costs and maximize positive outcomes through pooling resources, knowledge, and innovative technologies.

- **Public-private partnerships** are pivotal in driving scalable climate-resilience solutions.

- **Policy and financial support for technology integration is urgently needed**, developing the approach adopted by the loss and damage fund announced in late 2023 at COP28 in Dubai.

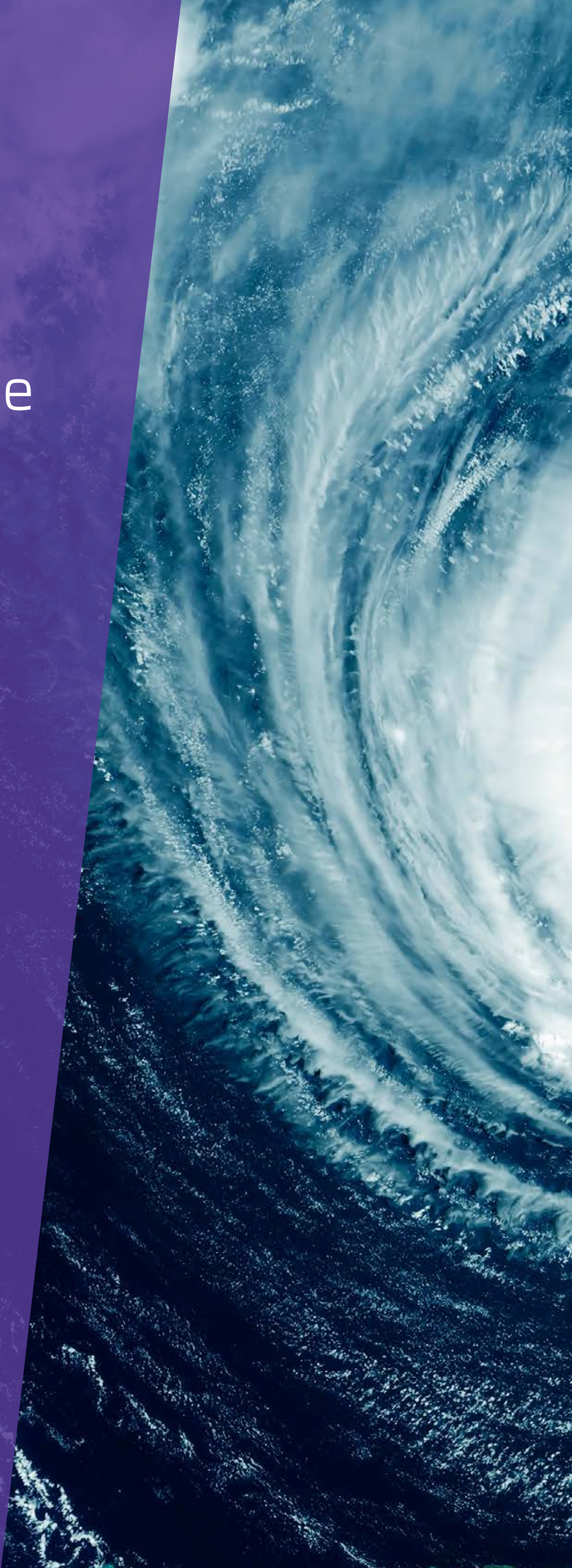
- **Policies to bridge the digital divide must recognize that climate and disaster risk data is a public good** and a core component in collaborative climate disaster impact management and risk mitigation.

- **Building a culture of innovation and preparedness** is a priority. Governments must develop comprehensive national frameworks aligned to their Nationally Determined Contributions and included in their National Adaptation Plans.

While collaboration is essential, governments must lead with comprehensive policy frameworks that incentivize innovation and ensure robust adaptation strategies are in place, including investment in R&D and support for community engagement.

PART ONE

The Cost Of Climate Change



The natural world is in turmoil. From destructive wildfires and tropical storms to droughts and floods, the planet is experiencing unprecedented environmental upheaval. The evidence that this increase is driven by accelerating climate change is compelling. According to the International Monetary Fund, weather-related disasters have increased three-and-a-half times since 1980, with 2023 being one of the hottest years on record. It appears irrefutable that rising global temperatures are amplifying weather extremes and that this profoundly impacts ecosystems, economies, and communities.

To give just a few examples:

Water-related disasters and tropical cyclones are now the leading cause of reported human and economic losses worldwide[4].

In vulnerable regions across the world, between 3.3 billion and 3.6 billion people are exposed to the impacts of climate change[6].

Climate- or water-related disasters are reported to have caused over 2 million deaths and $4.3 trillion of economic losses between 1970 and 2021, disproportionally impacting Least Developed Countries (LDCs), Small Island Developing States (SIDS), and landlocked developing countries[5].

$4 trillion in corporate assets could be at risk by 2030 due to the impacts of climate change[7].

Beyond the humanitarian toll, natural disasters impose an immense financial burden. In low- and middle-income countries, this burden is compounded by a lack of resources, making recovery difficult and further deepening inequality.

This paper argues that innovation – across infrastructure, technology, and governance – and collaborations between governments, businesses, and communities are key to tackling these challenges. From the development of flood-resistant infrastructure to the deployment of AI-powered predictive tools and engagement with communities (see Part Three of this report for detailed examples), there is a clear path to solutions that can mitigate nature’s increasing unpredictability.

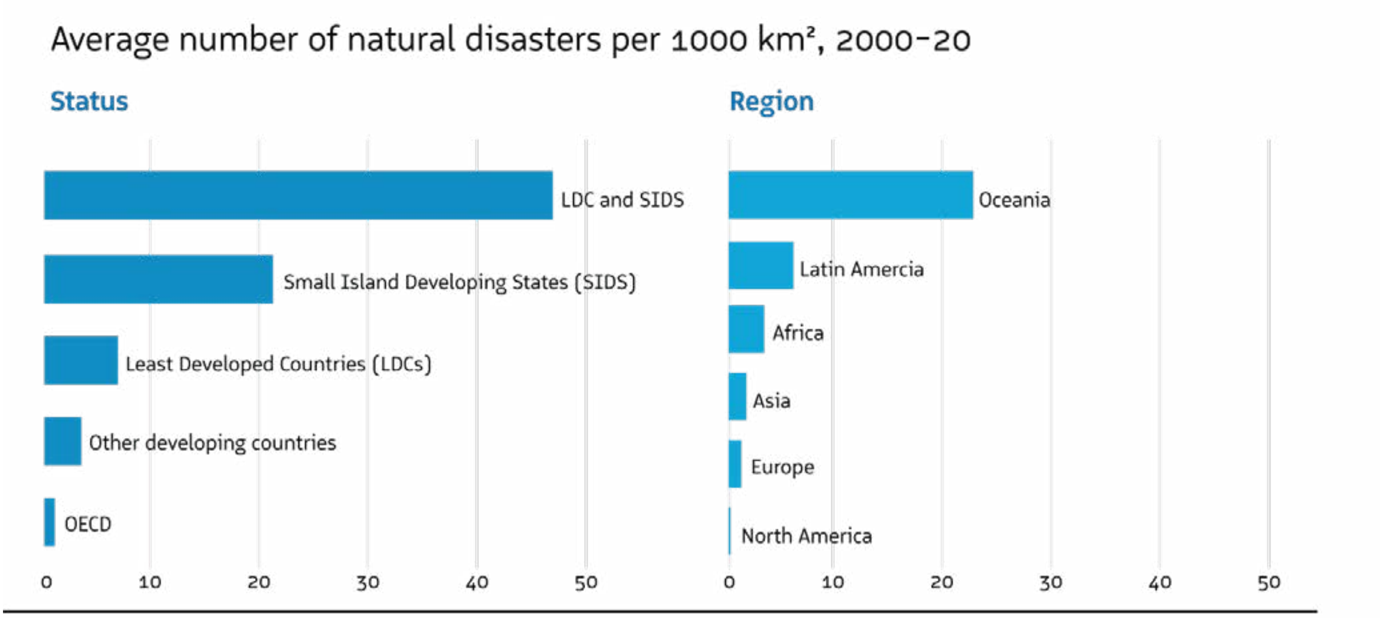
PART TWO

Climate Vulnerability Across The Globe

The frequency and intensity of extreme weather events are increasing year-on-year and impacting regions and countries indiscriminately. However, developing states are more vulnerable to the effects of such climate-related events. Climate change disproportionately affects low-income populations with fewer resources and less scope for adaptation, exacerbating existing inequalities and poverty. These populations are often more exposed to immediate impacts and are less able to recover from climate-related events (see Figure 1).

According to a 2022 report by the United Nations Environment Programme (UNEP), developing nations will require an annual financial commitment ranging from $215 billion to $387 billion throughout this decade to effectively address and mitigate the impacts of global warming[8]. The Paris Agreement, a pivotal component of international climate policy, recognizes these disparities and aims to address them through its mechanisms. It includes commitments to enhance support for climate change adaptation and increase the ability of developing countries to respond to climate impacts, facilitated by the Green Climate Fund and other financial mechanisms. These provisions aim to reduce the vulnerability of those most affected and enhance the capacities of countries that lack the resources to tackle climate change effectively.

Figure 1: **Natural Disasters by Development Status and Region**

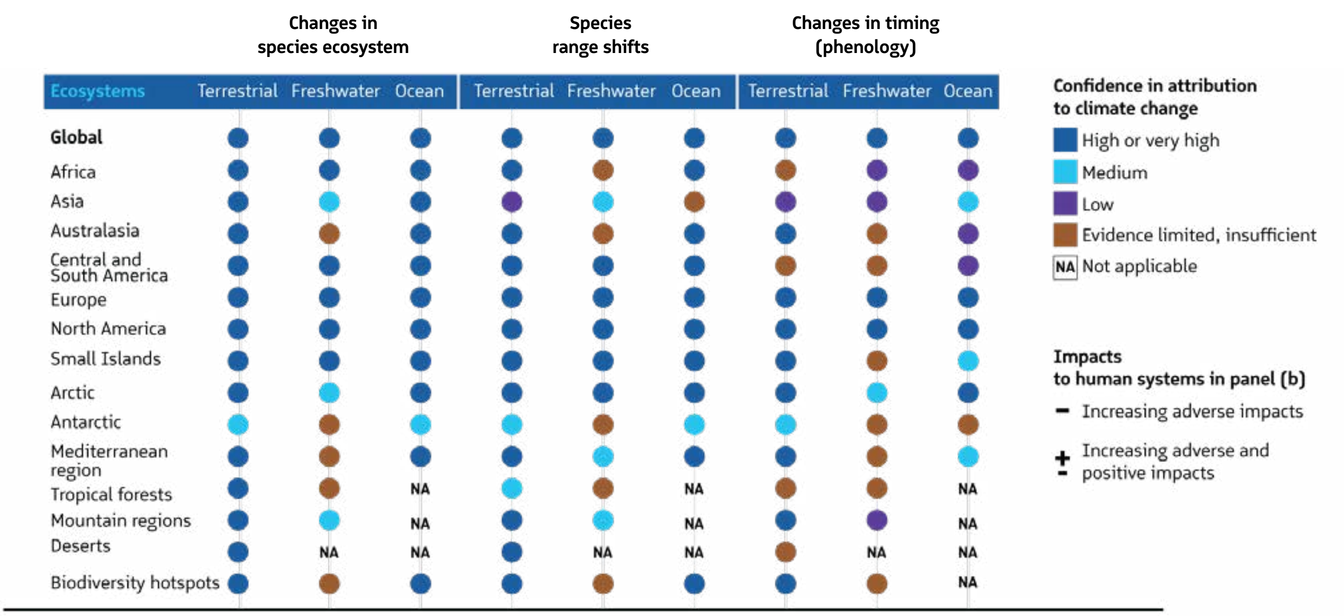


Status: The categories are not mutually exclusive. "Other developing countries" include all DAC recipient countries that are non-LDC, including low-middle income and upper-middle income countries. • Source: OECD (2024), Infrastructure for a Climate-Pacilient Future.

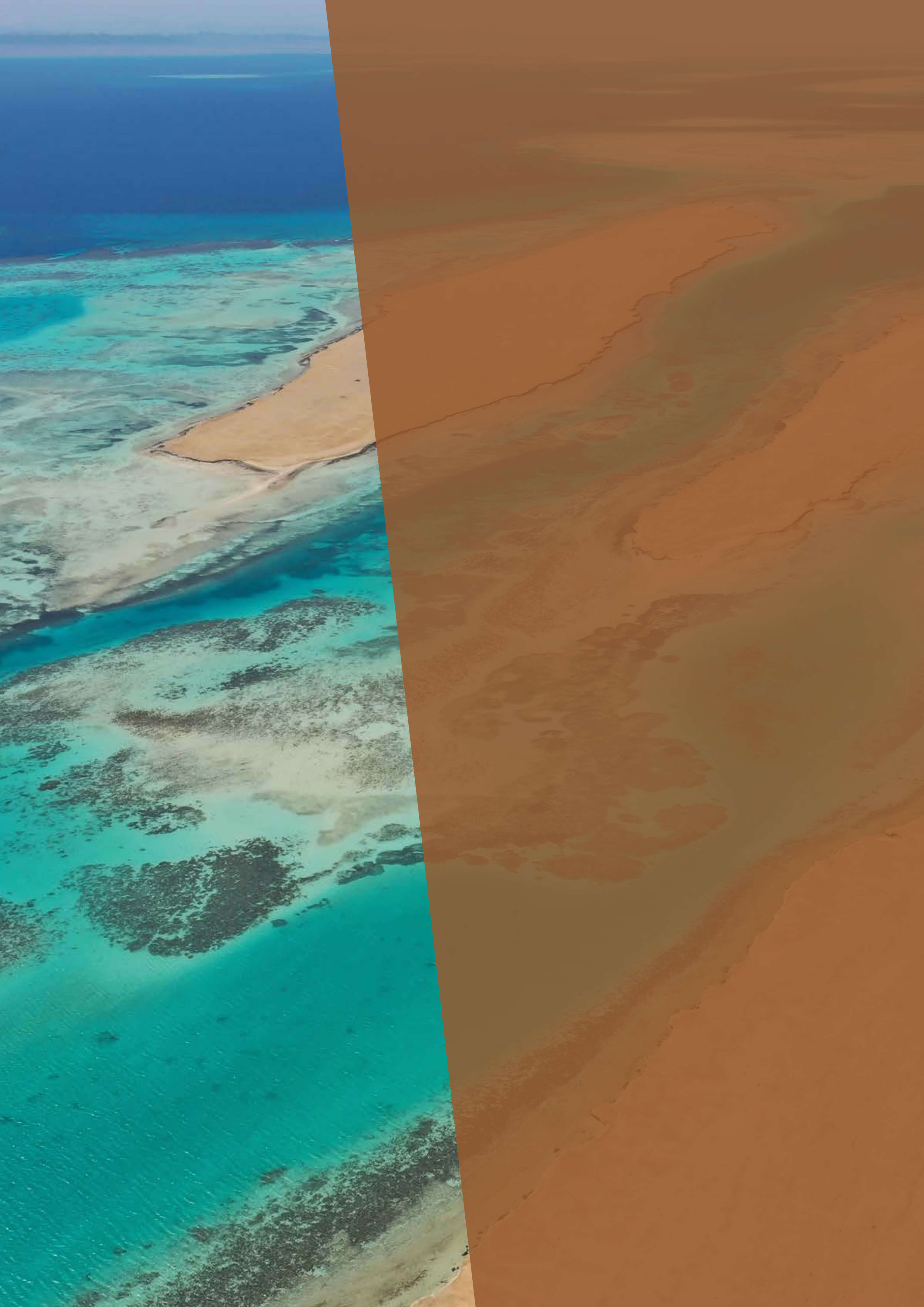
No state or region is immune to the effects of climate change on ecosystems: the observed impacts range from changes in the structure of terrestrial and marine ecosystems to effects on species in all known habitats (see Figure 2).

Figure 2 illustrates with high confidence that climate change is causing substantial alterations in ecosystem structures, such as habitat degradation and biodiversity loss. It also shows with varying degrees of confidence that species are shifting their geographic ranges in response to changing climatic conditions, and phenological events are occurring at different times than historically recorded. Regions such as Africa and SIDS show significant vulnerability due to their limited adaptive capacity and greater dependency on affected ecosystems.

Figure 2: **Observed Impacts of Climate Change on Ecosystems**



Source: Slide 5 of the presentation of the IPCC Co-Chairs, 2022. SPM Figure 2, IPCC WGII AR6: Observed global and regional impacts on ecosystems and human systems attributed to climate change, 2022.



According to the Intergovernmental Panel on Climate Change (IPCC), the effects of rising temperatures and the impacts of associated hazards will vary region by region, in some cases generating losses equivalent to significant percentages of annual GDP. Figure 3 shows a breakdown of selected climate-related hazards and consequent impacts from around the world as identified by the IPCC.

Figure 3: **Global Hazards and Impacts**

Hazard type	Impact from the IPCC report	How the hazard is impacting regions across the globe
Sea-level rise	• By mid-century, about one billion people living in low-lying cities and other settlements on the coast are projected to be at risk from sea-level rise and other climatic hazards.	• Global sea levels have risen by 15-25cm since 1900. The World Bank reports likely annual damage from sea-level rise at $1 trillion by 2050 if unmitigated.
Drought	• The regional impacts of climate change on major crop yields and food production are evident worldwide, including for crops, fisheries, livestock, and aquaculture. All these sectors are important for food security. With 1.3 billion people relying on agriculture as the main source of income, drought is putting the livelihood of many at risk, often halting and reversing gains in food security and poverty reduction[9].	• In Kenya, drought accounts for a loss of approximately $500 million per year, which is equivalent to 2% of the country's GDP.
Heat stress	• Extreme heatwaves have led to increased mortality rates and strained public health systems. High temperatures disrupt urban living conditions, impact labor productivity, and exacerbate health conditions in vulnerable populations.	• The summer of 2023 was the hottest worldwide on record since 1850[10]. In Europe, the 2003 heatwave resulted in over 70,000 deaths. The IPCC projects that with a 1.5˚C increase in average temperatures, 14% of the global population will experience severe heatwaves every five years.

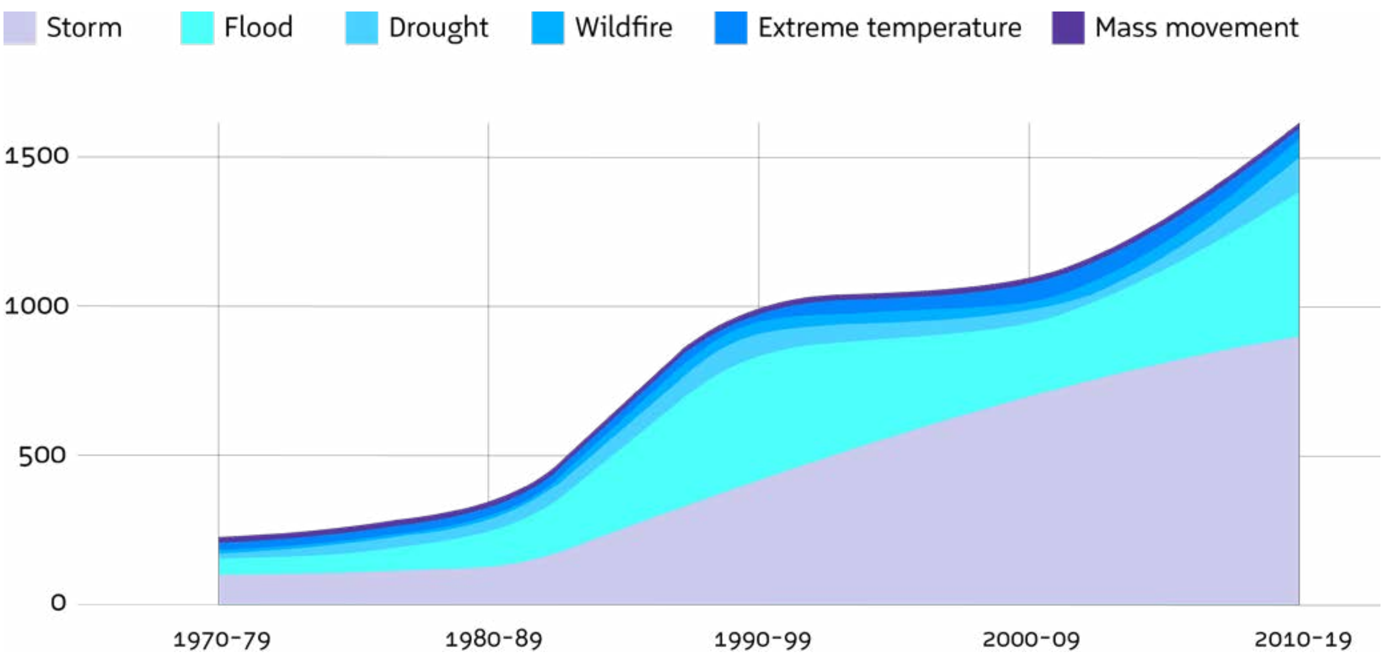
Hazard type	Impact from the IPCC report	How the hazard is impacting regions across the globe
Cold	• While extreme cold events are less common, they still pose risks to infrastructure and energy supply, particularly in regions unaccustomed to severe winter conditions.	• UNDRR notes that cold waves in recent years have impacted parts of the US and Europe, causing infrastructure damage and fatalities.
Fire	• Wildfires have severely impacted infrastructure, causing significant destruction to homes, power lines, and critical facilities.	• The Australian bushfires of 2019/20 burned over 18 million hectares, caused $100 billion in damage and affected nearly three billion animals.
Cyclones / Hurricanes	• Coastal and island communities face recurrent cyclone threats, which lead to substantial economic losses and disruptions to infrastructure, agriculture, and local livelihoods. Hurricanes also cause catastrophic damage, with long-term economic and social recovery challenges.	• The UN states that tropical cyclones in 2020 alone caused over $78 billion worth of damage globally, with Cyclone Amphan in South Asia displacing 4.9 million people. According to the World Bank, hurricanes now cost the US an average of $54 billion annually.

Climate-change-related disasters have multiple adverse impacts, including financial, agricultural, and biodiversity losses. We look at the types and extent of these impacts below.

Economic losses:

The economic impacts of climate change are profound and escalating. According to the World Economic Forum, climate-related disasters cost the global economy more than $200 billion in 2022, and this figure is expected to rise as extreme weather events become more frequent and severe. In low- and middle-income countries, economic losses are exacerbated by limited resources and inadequate infrastructure. For example, UNEP estimates that developing nations will need between $215 billion and $387 billion annually throughout this decade to effectively address and mitigate climate impact[11].

Figure 4: **Economic Losses From Climate-Related Extreme Events**



Mass movement: Hydrology-related events include avalanches, landslides, mudslides, rockfalls, and sudden subsidence.
Source: OECD (2024), Infrastructure for a Climate-Resilient Future.

Food and water insecurity:

Climate change threatens global food and water security by altering precipitation patterns, causing droughts and triggering floods. These disruptions impact agricultural productivity, affecting food supply and prices. The IPCC reports that major crop yields have already decreased by 4-10% globally over the past 30 years due to climate change, with future projections showing even greater risks to food security[16]. Water scarcity, driven by changing rainfall patterns and the melting of glaciers, currently affects over 1.5 billion people worldwide, and this number is expected to increase as climate impacts worsen[17].

Displacement and migration risks:

Climate-induced displacement is becoming a significant global challenge. The Office of the UN High Commissioner for Refugees (UNHCR) reports that an average of 20 million people are displaced annually due to weather-related disasters[12]. This displacement places immense pressure on urban infrastructure, social services, and economies, particularly in regions already facing socioeconomic vulnerabilities. Climate resilience is essential to reduce and manage these displacements, ensuring communities have the resources and infrastructure to remain stable and secure.

Health risks:

Climate change poses severe health risks, including heatwaves, pollution, and diseases spread by biting insects such as mosquitoes. The World Health Organization (WHO) estimates that, between 2030 and 2050, climate change could lead to approximately 250,000 additional deaths per year from heat stress, malnutrition, and diseases such as malaria and dengue fever[13]. Vulnerable populations, particularly in urban areas with poor infrastructure, are at greater risk of heat-related illnesses and respiratory problems due to air pollution. Strengthening health systems and incorporating climate-resilient healthcare infrastructure are vital for protecting public health.

Infrastructure damage:

Climate-related disasters such as hurricanes, floods, and wildfires cause extensive damage to infrastructure. The Global Facility for Disaster Reduction and Recovery (GFDRR) notes that damage to infrastructure from natural disasters costs low- and middle-income countries around $18 billion annually[14]. Estimates of the cost of rebuilding following Hurricane Helene in the US in 2024 range from $30.5 billion to $47.5 billion[15]. The destruction of critical infrastructure – including power grids, water supply systems, and transportation networks – disrupts economic activity and impedes recovery efforts. Building resilient infrastructure that can withstand extreme weather events is crucial for minimizing such damage and ensuring the continuity of essential services.

Biodiversity loss and ecosystem services:

Climate change is a primary driver of biodiversity loss, leading to a decline in ecosystem services vital for human survival, such as pollination, water purification, and carbon sequestration[18]. The Stockholm Resilience Centre reports that six out of nine 'planetary boundaries' (safe limits to the impact of human activities), including biodiversity integrity, have already been crossed[19]. Loss of biodiversity undermines natural resilience and exacerbates the vulnerability of human systems to climate shocks; preserving ecosystems through sustainable practices and integrated resilience strategies is essential to support both environmental and human wellbeing.

PART THREE

Leveraging Innovative Digital Technologies

The pattern of continued climate change and the intensification of associated impacts is clear. Yet, how should policymakers respond to reduce climate disaster risk and increase preparedness? One answer can be found in technology.

Data-driven and digital technologies are uniquely equipped to enhance adaptive capacity and address the complex, multi-variable challenges inherent in climate decision-making. These technologies have the potential to navigate the interconnected nature of environmental, socioeconomic, and economic systems, managing numerous variables and uncertainties while supporting coordinated climate action across varying timelines and objectives.

Growing alignment between scientific advances, supportive policies, and market demand is fueling innovation in climate-adaptation technologies. This convergence is creating new avenues for organizations and communities to build resilience and respond proactively to environmental risks. Innovative resilience technologies and real-time data analytics are required to develop a holistic approach to disaster mitigation, fostering an adaptable and proactive strategy to combat the growing threat by fusing technology, data, and specific regional needs.

Now is the time for governments, NGOs, communities, and private companies to leverage the following digital applications for climate management and mitigation of risks and impacts:

Early-warning systems and multi-hazard platforms

Early-warning systems (EWS) and multi-hazard platforms have proven to be critical in climate disaster risk management, offering real-time data that enables timely alerts to mitigate impacts. Digital EWS can improve outcomes by giving communities valuable lead time to prepare for the effects of climate extremes. Innovations include mobile alerts, AI-driven predictive models, and satellite-based monitoring. The Early Warnings for All initiative launched at COP27 in 2022 exemplifies how cross-border partnerships can use these technologies to enhance global response capabilities, with an ambitious goal of expanding EWS to protect every person everywhere by the year 2027. This initiative has the potential to save millions of lives and reduce losses and damage – yet, today, only half of the world's countries are covered by an EWS[20], and while being ambitious and essential, several challenges and gaps must be addressed to achieve universal coverage of this initiative. These include reaching vulnerable and underserved regions[21], improving infrastructure for data access, monitoring and forecasting capabilities[22], enhancing governance, and coordination among various stakeholders, including government agencies, non-governmental organizations, and local communities, as well as mobilizing sufficient financial resources to fund the development and maintenance of EWS[23].

Earth observation and remote sensing

Satellite imagery and remote sensing offer comprehensive data on land, ocean, and atmospheric changes. Platforms like Destination Earth (DestinE) simulate climate and human activities to forecast events such as floods and droughts, providing the high-precision analysis crucial for preemptive planning. These technologies can form the backbone of resilience strategies by monitoring environmental shifts and helping policymakers anticipate risks.

Advanced digital technologies

Among the emerging climate hazard mitigation and adaptation tools, a suite of data-driven and digital technologies powered by artificial intelligence (AI) is proving effective for climate adaptation. This suite includes drones, the Internet of Things (IoT), augmented reality and virtual reality (AR and VR), advanced computing, and AI. Together, they constitute a pioneering toolkit, allowing for more responsive and adaptive measures in the face of climate challenges.

Figure 5 highlights particular technology use cases in greater detail.

Figure 5: **Technologies, Use Cases, and Implementations**

Technology	Objective / Application	Use cases	Impact	Examples
Artificial intelligence Advanced analytics, machine learning, deep learning, and large language models.	Strengthen planning and decision-making.	Climate modeling, weather modeling, climate risk analytics.	Analyze very large datasets to understand patterns and project impacts. Preparation for potential climate threats.	Brazilian start-up Sipremo employs AI to predict the incidence and type of climate disasters in the Americas, Asia, and Europe.
Advanced computing Supercomputing and quantum computing.	Cross-cutting coordinated approaches to complex problems.	Cloud-based supercomputing to power GPU-based climate models.	Powering detailed climate models and simulations.	The European Centre for Medium-Range Weather Forecasts (ECMWF) uses advanced computing to enhance predictions[24].
Internet of Things Networked devices, including sensors and hand-held devices.	Gather, complete, and process data.	Distributed data collection such as networked heat sensors.	Early detection of extreme weather conditions supporting rapid response and adaptive strategies.	In California, PanoAI utilizes an IoT-based platform combining cameras and data feeds for early wildfire detection[25].
AR/VR Immersive visualization tools, including headsets.	Promote adaptive behaviors.	Visualize climate impacts such as polar tipping points.	Immersive simulations for first responders and policymakers.	An immersive experience called the Climate Tipping Points Hub, introduced by the World Economic Forum and its partners, uses 3D simulations and VR experiences to show the escalating domino effect of climate change impacts like disappearing Arctic sea ice[26].
Drones Unmanned aerial vehicles (UAVs) with cameras and carrying capacity.	Gather, complete, and process data.	Aerial data collection from physical features and assets using thermal imaging and LiDAR laser sensing technology.	Rapid data collection in hard-to-reach areas post-disaster, supporting search and rescue missions and damage assessment.	In Mozambique, the Be-Resilient project employs drones with sensors to predict flooding patterns[27].
Earth observation Remote sensing, such as satellites, or in-situ techniques, such as weather stations.	Gather, complete, and process data.	Data collection to advance scientific understanding of atmospheric conditions.	Real-time Earth observation enables EWS; satellite data allows for continuous monitoring of key climate indicators.	The European Space Agency's satellites have revealed new insights into climate change, including ice melt and freshwater resources, informing adaptation strategies[28].

Preparedness Demands Technology

Preparedness is the essence of climate-related disaster mitigation. AI and smart technologies already empower communities by making disaster warnings more accessible and actionable. They bridge the gap between detection and response, enabling more proactive disaster management. Mobile applications integrated with AI offer tailored alerts, evacuation routes, and emergency contacts and can ensure that people receive relevant information in real time. They are also helping train local populations in emergency response and evacuation procedures.

By providing accurate predictions and timely alerts, these technologies are helping societies move from crisis management to risk reduction. Applications include customized alerts where AI-based systems analyze individual locations and exposure levels, delivering personalized warnings to residents and businesses, and crowdsourced data platforms that allow communities to contribute real-time data on hazards, such as blocked roads or damaged infrastructure, enhancing situational awareness for responders.

PART FOUR

Unlocking Scalable Solutions Through Collaboration

In recent years, partnerships between governments, businesses, and communities have emerged as powerful models for developing disaster resilience and mitigation strategies. Several studies[29] have found that, during disasters, a community-led response – with government and non-profit support – is essential for rapid, widespread action that saves lives. These collaborations showcase how pooling resources, knowledge, and innovative technologies can drive scalable and sustainable solutions, helping communities tackle the unprecedented challenges posed by climate change.

The following case studies highlight the critical role of collaboration in developing effective disaster risk-reduction strategies. From minimizing tsunami disaster risk in Japan to cyclone management in Bangladesh and wildfire control in California, each example underscores the value of innovative approaches and public-private and cross-sectoral partnerships which leverage diverse expertise and resources. As natural disasters intensify globally, adopting similar models of multi-stakeholder engagement can foster more resilient societies.

Case Study: Japan's Tech-Driven Approach To Mitigating Natural Disasters

Japan is vulnerable to various natural disasters, including earthquakes, typhoons, and floods. To mitigate the impacts, the country has taken a proactive, tech-driven approach, integrating state-of-the-art technology with coordinated government and community efforts.

Sendai, a city in Miyagi Prefecture, is one of 108 designated tsunami-threatened areas in Japan. The city endeavors to minimize human casualties from tsunamis by ensuring timely and reliable communications that bring together technology and business. The city has invested in an emergency announcement system that uses fully automated drones to urge people to evacuate when tsunami alerts are issued[30]. Developed through a public-private partnership between the city and four technology companies, the drone system calls for evacuation along an approximately 8-kilometer section of the coastal area between Miyagino-ku and Wakabayashi-ku, Sendai.

The main feature of the drone system is its use of a dedicated private wireless communication network, which is free from disruption even in the event of a disaster. An infrared camera mounted on a drone takes pictures of disaster victims and other objects while in flight. It then transmits them to the city's disaster response headquarters, enabling personnel to assess the damage and threat to life in remote areas safely and in real time. Drones can be dispatched faster than helicopters, and the system is expected to work with the police and fire departments in the future to share information on impassable routes, fires, and power outages, increasing the speed of rescue operations. The advanced, tech-driven mitigation strategies developed by Japan can serve as models for other countries facing similar vulnerabilities.

Approaches that countries can replicate include:

Earthquake EWS[31] that detect initial tremors and promptly alert the public via smartphones and broadcast media. This enables individuals to take immediate protective actions. Implementing similar systems elsewhere can enhance preparedness and reduce casualties.

Japan's Monitoring of Waves on Land and Seafloor (MOWLAS) network[32] integrates various observation systems to monitor earthquakes, tsunamis, and volcanic activity in real time. Establishing comprehensive monitoring networks can improve disaster response times and accuracy in other regions.

Development of seismic-resistant infrastructure[33], such as seismic dampers and base isolation systems, has enhanced the resilience of Japanese structures. Adopting and adapting these construction techniques can strengthen infrastructure in disaster-prone areas globally.

Japan emphasizes disaster education[34], conducting regular drills and distributing comprehensive disaster preparedness manuals like "Tokyo Bosai"; implementing such educational programs can empower communities to respond effectively during emergencies.

Case Study: Bangladesh's Multilayered Early-Warning System for Extreme Weather Events

Bangladesh is one of the most disaster-prone countries in the world, experiencing frequent cyclonic storms. This extreme weather vulnerability is compounded by the country's funnel-shaped seaboard in the northern Bay of Bengal, where floods and erosion frequently cause devastation in the low-lying coastal region, causing loss of life and the displacement of millions of people over recent decades.

Compared to other highly vulnerable nations, Bangladesh's proactive approach to early-warning systems is notable. Many countries, particularly in Africa, face challenges establishing effective systems due to limited infrastructure, funding, and technical expertise. For instance, Africa has the world's least developed weather and climate observation network, with only two out of 53 African World Meteorological Organization (WMO) countries meeting basic observation standards[35]. The United Nations has recognized the critical need for investment, as countries with low early warning coverage experience nearly six times higher disaster mortality rates than those that have invested in such systems. Despite this, only one-third of LDCs and SIDS have the capability to alert citizens about impending hazards[36].

Bangladesh began investing heavily in weather forecasting technology, cyclone shelters, and training a network of volunteers along the coast following Cyclone Bhola[37] in 1970, which resulted in the death of an estimated half a million people in the Bay of Bengal. Today, the country has a multi-layered early-warning system[38] managed by the Storm Warning Centre (SWC)[39] – a regional center of the Bangladeshi Meteorological Department. The early-warning system uses a comprehensive network of weather stations, including coastal radars, ground-based stations and balloon-borne instruments measuring air pressure and humidity, to monitor developments in real time. The SWC detects and monitors cyclones from formation until landfall, forecasting the cyclone's path. It then issues warning messages using various communication methods, including TV and radio broadcasts, push messages via mobile phone networks, targeted SMS notifications, and a helpline that people can call to listen to pre-recorded voice messages.

The key to disaster risk reduction is reaching as many people as possible and this is enabled by the country's extensive network of volunteers. They are tasked with ensuring that as many people as possible are aware of the latest weather risk warnings using myriad measures to inform communities. These include street patrols and going door-to-door to disseminate information to those who are housebound, illiterate, or without access to a mobile phone.

The result is that intelligent tools supported by improved access to information and community management have successfully lowered the death toll and enabled residents of coastal areas to evacuate safely and in time to nearby cyclone shelters.

Case Study: Integrated Wildfire Management In California

Even before the devastating fires around Los Angeles in early 2025, which at the time of writing had claimed 28 lives and destroyed more than 16,000 buildings[40], California was dealing with an escalating wildfire crisis. Decades of fire suppression, coupled with the increasing impacts of climate change, have dramatically increased wildfire size and intensity throughout the state. Wildfires have destroyed thousands of buildings, forced hundreds of thousands of people to flee their homes, and exposed millions of residents to polluted air[41]. The crisis has prompted innovative collaborations aimed at managing and preventing fires. A prime example is the California Wildfire & Forest Resilience Task Force[42], established in 2018 as a collaborative effort between federal, state, and local governments as well as public, private, and tribal organizations. The aim was to introduce a more integrated approach toward effective forest management and to bring the best available science to forest management and community protection efforts.

In January 2021, a Wildfire and Forest Resilience Action Plan[43] based on recommendations from the California Forest Management Task Force was introduced to strategically accelerate efforts to restore the health and resilience of California forests, improve the fire safety of communities, and sustain the economic vitality of rural forested areas. One of its goals is to drive innovation and measure progress by using the best available science and accelerating applied research. The California Air Resources Board and the California Department of Forestry and Fire Protection are developing state-of-the-art models to simulate interactions between climate, fire, carbon, and water in forests. This modeling will help determine management strategies to deliver on the state's climate-change goals while providing other valuable ecosystem services. Additionally, the Action Plan outlines the development of a Forest Data Hub to integrate, evaluate, and synthesize ongoing reporting and monitoring efforts conducted by state and federal agencies, universities, and non-governmental organizations.

The Action Plan also seeks to strengthen the protection of communities through community risk reduction and adaptation planning. This is to be achieved by developing a best-practices guide for new and updated Community Wildfire Protection Plans and increasing information sharing through an organized peer networking effort to facilitate learning and preserve institutional knowledge of wildfire-mitigation planning across disciplines.

PART FIVE

The Way Forward: A Global Call To Action

The rising number of natural disasters demands urgent, coordinated global action to manage impacts and reduce risk. Innovation on an unprecedented scale is imperative. This will require a collective effort from governments, businesses, and communities to create robust policies, invest in resilient technologies, and foster proactive community engagement. By leveraging technology and collaborative frameworks, it is possible and realistic to create adaptive capacities and develop comprehensive solutions for climate resilience.

Policy, community, and collaboration

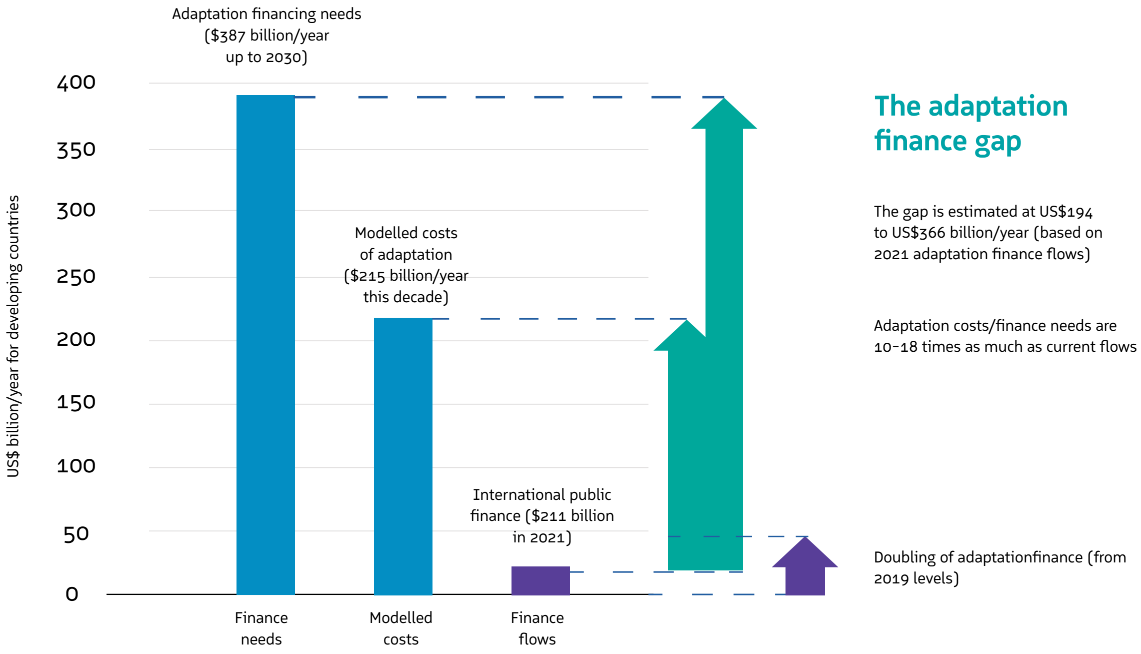
Digital solutions have the potential to redefine how we adapt to climate change, offering unprecedented opportunities to strengthen resilience across the globe. However, their adoption faces significant barriers. Technological challenges, such as inadequate infrastructure and a persistent digital divide, hinder access, especially in developing regions. Issues with data availability, quality, and siloed ownership further complicate the integration of digital tools, while high deployment costs and limited funding impede progress. Regulatory gaps, including inconsistent policies and privacy concerns, create uncertainty, and slow policy responses often fail to keep pace with rapid technological advancements. Additionally, limited awareness, cultural resistance, and mistrust of digital solutions exacerbate these challenges, particularly among marginalized communities.

To overcome these barriers and for such solutions to be effective, they must be supported by robust policy frameworks, active community engagement, and strong global collaboration. A multi-stakeholder approach is essential for scaling these technologies rapidly and enhancing our collective ability to respond to climate threats.

Public-private partnerships are pivotal in driving scalable climate-resilience solutions. By pooling resources, knowledge, and expertise, these collaborations facilitate innovation and ensure that technological advancements are integrated into practical applications. For example, Japan's tech-driven approach to mitigating tsunami risks with drone-based emergency communication systems demonstrates the impact of coordinated efforts between government and private tech companies. Such partnerships can be replicated globally, especially in regions with high climate vulnerability.

Current financial flows are insufficient to meet adaptation needs, particularly in developing countries: **policy and financial support for technology integration is urgently needed.** The adaptation finance gap is estimated to be between $194 billion and $366 billion per year – the equivalent of up to 18 times greater than current financial support[44]. The loss and damage fund announced in late 2023 at COP28 in Dubai represents a critical step toward addressing these deficits, aiming to direct finance to the most vulnerable countries. However, sustainable funding mechanisms must be developed and supported by policies that encourage experimentation and investment in climate-resilience technologies.

Figure 6: **The Adaptation Finance Gap**



Closing the adaptation finance gap necessitates innovative mechanisms and partnerships that effectively mobilize resources for climate resilience.

Examples where stakeholders have come together to innovate and apply financing mechanisms include:

- **Debt-for-climate swaps** involve restructuring a country's debt obligations in exchange for commitments to invest in climate adaptation projects. This mechanism alleviates debt Barbados's while directing funds toward resilience-building initiatives. A notable example is Barbados's recent 'debt-for-climate resilience' swap, which freed up $165 million for water infrastructure, food security, and environmental protection projects[45].
- **Climate-contingent finance** structures repayments based on climate-related outcomes, aligning financial incentives with adaptation goals, reducing the risk for investors and encouraging proactive adaptation measures. This approach can finance previously under-funded efforts to address a wide range of risks, including extreme climate change[46].
- **Blended finance** combines public, private, and philanthropic funds to de-risk and attract private investment in adaptation projects. This approach addresses the high upfront costs and perceived risks of climate adaptation. The Global Innovation Lab for Climate Finance has developed instruments that have successfully mobilized over $380 million for adaptation projects, demonstrating the effectiveness of blended finance in this context[47].
- Issuing bonds specifically earmarked for adaptation projects, such as **green and resilience bonds,** can attract investors seeking sustainable investment opportunities. These bonds provide a fixed return while funding resilience-building initiatives. The African Development Bank's issuance of a $750 million "hybrid" bond to enhance climate finance efforts exemplifies this approach by pioneering a new asset class to scale up climate finance without burdening cash-strapped governments[48].

Bridging the digital divide means recognizing that climate and disaster risk data is a public good. As technology becomes mainstream in disaster management, digital divides become synonymous with a development divide; for example, only one out of four individuals in low-income countries used the internet in 2022[49]. Limited access to high-quality data and a lack of technical expertise among relevant practitioners are the greatest challenges to bridging these divides.

Building a **culture of innovation and preparedness** is a priority. Governments must develop comprehensive national frameworks aligned to their Nationally Determined Contributions to reducing carbon emissions as defined in the Paris Agreement, detailing medium- and long-term strategies to reduce climate vulnerabilities and adapt to a changing climate. Currently, 58 countries have submitted multi-sector National Adaptation Plans to the UNFCC, and 90% of them mention climate and disaster risk finance[50]. National Adaptation Plans should encompass detailed plans for infrastructure upgrades, emergency response mechanisms, and the integration of digital resilience technologies. By coordinating with private-sector partners and academic institutions, policymakers can build adaptive systems that are flexible, inclusive, and scalable. Governments should also engage and empower local governments to ensure regions have targeted plans for climate-resilience actions in their territory. By enacting policies that incentivize technological innovation, governments can accelerate the deployment of innovative tools and foster public-private collaboration. This enables a seamless transition from reactive crisis management to proactive risk mitigation.

Harnessing **nature-based solutions** can also provide cost-effective ways to protect infrastructure assets and services while contributing positively to conserving ecosystem functions and improving human health. Governments should foster these solutions across the policy, regulatory, finance, and institutional frameworks that enable infrastructure development[51].

Conclusion

Redefining Resilience In The 21st Century

The increasing frequency and intensity of climate-driven disasters presents a stark call to action for global stakeholders. Building climate resilience is not just an option but an urgent necessity. Governments must lead with comprehensive policy frameworks that incentivize innovation and ensure robust adaptation strategies are in place, including investment in research and development, public-private collaborations, and community engagement. Integrating innovative digital technologies offers a multifaceted approach to mitigate risks and build stronger societies. Bridging the digital divide and ensuring equitable access to high-quality data are essential for empowering vulnerable communities and supporting global efforts to reduce climate vulnerability. By committing to proactive and inclusive strategies, we can transform how we respond to climate challenges – fostering sustainability, enhancing resilience, and protecting human and environmental health for future generations.

The challenge of climate-induced disasters is formidable, but it is not insurmountable. Innovation offers a path forward, enabling societies to anticipate, prepare for, and adapt to environmental shocks. Through resilient infrastructure, AI-powered tools, and collaborative action, we can build a future that manages and mitigates the threat of natural disasters.

The question is not whether we can prevent disasters – some will inevitably occur – but whether we can respond intelligently and effectively to mitigate harm when they do.

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