GAR

Global Assessment Report
on Disaster Risk Reduction

GAR Special Report 2024

Forensic Insights for Future Resilience
Learning from Past Disasters

United Nations

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For additional information, please contact:
United Nations Office for Disaster Risk Reduction (UNDRR)
7bis Avenue de la Paix, CH1211 Geneva 2, Switzerland. Tel: +41 22 917 89 08

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UN Office for Disaster Risk Reduction

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Forensic Insights for Future Resilience

Learning from Past Disasters

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Contents

Kahiya Hassen Nur, a mother of five children, leads her goats to find pasture in Kilway village in Afdher zone that has been severely affected by drought

Source: UNICEF Ethiopia, 2022, Mulugeta Ayene

Source: Shutterstock

Foreword

Disaster risk is increasing across the globe and more people, and their assets, are increasingly vulnerable and exposed to that risk. While some increases in the numbers can be attributed to improved data collection, they primarily reflect the current state of affairs. This elevated risk, which is a sign of a clear resilience gap, is leading to larger and more frequent disasters with greater economic losses that are costing lives and livelihoods.

If we accept that disasters are neither natural nor inevitable, then we must work to prevent or at least reduce their impact. Developing countries cannot afford to lose any more ground to disasters, which are deepening inequality and derailing progress on the Sustainable Development Goals. Effective risk management requires risk governance that clearly differentiate between event-by-event responses and more comprehensive risk reduction that realizes multiple co-benefits.

This is where 'disaster forensics' comes in to inform decision-making, which is the focus of this 2024 special edition of the Global Assessment Report (GAR). The GAR 2024 Special Report aims to apply new insights on recent disaster events, to deliberately learn from the past to inform actions in the present and to shape tomorrow's resilience. This means identifying underlying roots causes of disasters within broader social, economic and institutional drivers and conditions, as well as entry points for decision-making so that risks can be recognized, evaluated, and addressed. The success of countries to develop legislative instruments to manage risk will be limited without simultaneous efforts to combat practices that create risk.

Using ten case studies, the GAR Special Report 2024 aims to demonstrate the value of the forensics approach, especially when combined with a projection of future risks. The knowledge gained from this process is invaluable to identifying resilience gaps, guiding risk reduction investments, and reforming regulatory systems for resilience.

As much of the infrastructure needed to support our growing human population has yet to be built, we owe it to future generations to leverage every opportunity to inject resilience into our investments. This starts with understanding the past to build a more resilient future.

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Coordinating lead author: **Jenty Kirsch-Wood**, UNDRR; Lead authors: **Irasema Alcantara-Ayala**, The National Autonomous University of Mexico; **Roger Pulwarty**, NOAA; Co-lead authors: Disasters Avoided - **Ilan Kelman**, University College London; **Gareth Byatt**, Risk Insight Consulting; **Ana Prados**, University of Maryland; Project coordinator: **Rhea Katsanakis**, UNDRR; Project support: **William Penagos**, UNDRR, **Mariavittoria Dona**, UNDRR Intern; UNDRR internal review: **Paola Albrito**, **Loretta Hieber Girardet**, **Jeanette Elsworth**, **Mayleen Cabral**, **Jair Torres**, **Jennifer Guralnick**, **Chiara Menchise**, **Saira Ahmed**, **Adair Ackley**, **Roberto Schiano Lomoriello**, **Muliro Mashauri**, and **Diana Mosquera Calle**. UNDRR communications and outreach: **Jeanette Elsworth**, **Fanny Langella**, **Omar Amach**, **Rosalind Cook**, **Sophie Richter** and **Ken Hawkins**.

Collecting water at the UNDP-funded dam in Baligubadle, Somaliland, northwest Somalia

Source: UNDP Somalia

Contributing authors include:

Chadi Abdallah, National Council for Scientific Research, Lebanon; **Carlos Mendes**, Portuguese National Authority for Emergency and Civil Protection; **Fantina Tedim**, University of Porto; **Dayra Carvaja**l, **Kimerly Coleman**, Federal Emergency Management Agency (FEMA), USA; **Tegan Chappell, Tim Denison, Keith Smith**, Public Safety Canada; **Tyler Redgun–Solway**, National Fire Management Program Parks Canada; **Anna Tucker-Abrahams, Michelle Edwards, Sashagaye Vassell**, Office of Disaster Preparedness & Emergency Management, Jamaica; **Irasema Alcantara-Ayala**, The National Autonomous University of Mexico; **Antonio Benavides Rosales, Rafael Humberto Marín Cambranis, Alma Mungaray Lagarda, Natalia Reyna**, Secretaría de Gestión Integral de Riesgos y Protección Civil, Mexico; **Alonso Brenes Torres**, University of Costa Rica; **Allan Lavell**, Latin American Social Science Faculty; **Gideon Galu**, FEWSNET; **Ronald Jackson, Paul Conrad**, UNDP; **Filipe Domingos Freires Lúcio**, WMO, **Antonio José Beleza,** SADC Humanitarian and Emergency Operations Center (SHOC);, Mozambique; **Adérito Celso Félix Aramuge Aramuge,** National Institute of Meteorology of Mozambique; **Annie Mapulanga,** Department of Disaster Management Affairs, Malawi; **Lucy Mtilatila, Keenness Mang'anda,** Department of Climate Change and Meteorological Services, Malawi; **Nirivololona Raholijao, Randrianarison Solomampionona Rivo Herilala,** National Meteorological Service, Madagascar; **Ranoeliarivao Tsirihasina Sitraka,** National Office for Risk and Disaster Management, Madagascar; **Sébastien Langlade,** Meteo-France Indian Ocean Interregional Center, La Réunion; **Dilanthi Amaratunga,** University of Huddersfield; **Raditya Jati, Fitriatun Hidayati, Oktavi Andaresta,** National Disaster Management Authority of Indonesia; **Jesus San-Miguel,** JRC; **Gareth Byatt, Gareth Byatt**, Risk Insight Consulting.

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Executive Summary

- Disaster risk is increasing. More intense shocks and stresses are exacerbating inequality and derailing progress on the Sustainable Development Goals.

- Hazard events are becoming more intense and frequent in all regions of the world. When vulnerability and exposure levels are high, then these hazard events are much more likely to become disasters. In today's complex risk environment, the past is no longer a reliable guide to the future. Active learning and enhanced resilience-building approaches are essential for rapid adaptation to an increasingly abnormal and unpredictable climate future.

- Extreme disasters are not "normal". Recent climate hazard events have exceeded historical norms as well as the projections of many risk models. Human choices, particularly the burning of fossil fuels, are driving these changes. They also intensify natural cycles like El Niño, making them more extreme and volatile.

- Everyday decisions in urban planning, infrastructure, poverty reduction, and environmental management are also exacerbating disaster risks. In such cases, our collective knowledge on risk reduction is not being applied to address current, new and and emerging challenges.

- It does not have to be this way. Proactive measures to remove obstacles to sustainable development by reducing vulnerability and exposure to hazards can act as shock-absorbers, buffering the impact of increasingly intense hazard events. The sustainable development of future generations requires us to embed resilience as a core principle that underpins engineering, ecology and social development.

- In the same way that athletes learn from setbacks and successes to improve performance, governments and communities must also strengthen their resilience, flexibility, and agility in the face of future hazard events.

- Resilience provides immediate benefits and creates the essential buffers that help to stabilize systems and markets in an era of increasing natural hazards and wider threats.

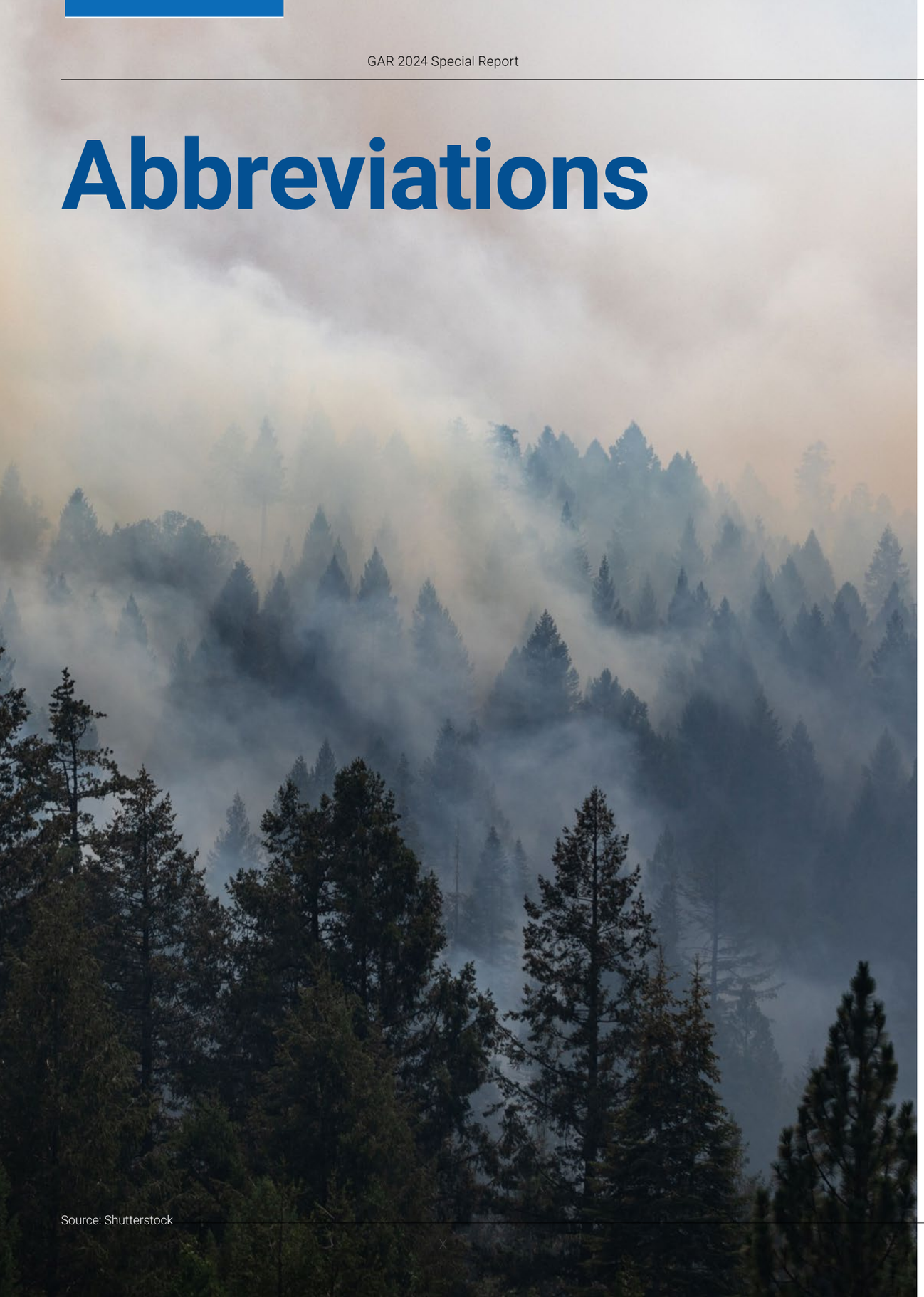
- In areas where infrastructure is present but strained by more intense events, a forensic understanding of disaster impacts on people, planet and prosperity can help to refine risk reduction strategies and focus on avoiding disasters. Nature-based solutions, such as protecting wetlands to absorb floodwaters or preserving coastal forests to buffer against storms, are key assets in reducing vulnerability and exposure of people and assets.

- Applying these approaches requires listening to communities and local experts, leveraging existing knowledge and collaborating to upgrade strategies based on future trends and using systems-thinking. It also demands systems that measure and learn from disasters, quicker replication of successful strategies in the context of local geographies, and adjustments when challenges arise.

- Perhaps most importantly, much of the infrastructure and services needed to support our growing human population has yet to be built. Wise and proactive governments will see this as a prime opportunity to hard wire-resilience and a disaster-avoidance mindset into the fabric of our future cities and communities, benefitting both current and future generations.

Source: Flickr/Toon van Dijk (CC BY-ND 2.0)

Abbreviations



Source: Shutterstock

AR	Assessment Report, published by the IPCC for each assessment cycle
AR6	Sixth Assessment Report
ARC	African Risk Capacity
CAMS	Copernicus Atmosphere Monitoring Service
CEPAL	Economic Commission for Latin America and the Caribbean
CPI	Consumer Price Inflation
DRM	Disaster risk management
DRR	Disaster risk reduction
EAC	East African Community
ENSO	El-Niño-Southern Oscillation
E-SHMP	Enhanced State Hazard Mitigation Plan
EU	European Union
EWS	Early warning system
FAO	Food and Agriculture Organization of the United Nations
FORIN	Forensic Investigations of Disasters
GAR	Global Assessment Report
GDP	Gross Domestic Product
GFW	Global Forest Watch
GWIS	Global Wildfire Information System
IFRC	International Federation of the Red Cross
IGAD	Intergovernmental Authority on Development
IOD	Indian Ocean Dipole
IOM	International Organization for Migration
IPCC	The Intergovernmental Panel on Climate Change
NDC	Nationally Determined Contribution
NEWSP	National Early Warning System Platform (Lebanon)
ODH26	Overheating Degree Hours above 26°C
PM2.5	Particulate Matter that is 2.5 microns or less in diameter
SDG	Sustainable Development Goal
SMEB	Survival Minimum Expenditure Basket
SNNP	Southern Nations, Nationalities, and People's, a region in Ethiopia
SNS	Serviço Nacional de Saúde (Portugal's National Health Service)
UN	United Nations
UNDP	United Nations Development Programme
UNDRR	United Nations Office for Disaster Risk Reduction
UNFCCC	United Nations Framework Convention on Climate Change
UNHCR	United Nations Refugee Agency
WUI	Wildland-Urban Interface
WVG	Western V Gradient

Part 1: Introduction

By the time that Cyclone Freddy split into several smaller storms in March 2023, it had spent a total 36 days travelling from the Australian coast and across the Indian Ocean before smashing into Madagascar, Mozambique, and Malawi. Breaking multiple records for its power and energy, Freddy's category five winds brought rain, mudslides, and storm surges. And when it was over, Freddy had killed more than 400 people and left a trail of wreckage across the region, including tens of thousands of migrants. Meteorologists said the storm was unprecedented.

Less than a year later however, Hurricane Beryl, caused similar amounts of damage. The earliest category five hurricane ever recorded, Beryl battered the Caribbean region, destroying or severely damaging as many as 90 percent of homes in some areas. One of the most powerful storms to ever pummel Jamaica and other Caribbean nations, Beryl also left millions in the US without power.

As global temperatures increase, shattering new records all around the world, more and more countries are reporting disastrous hazard events. In July 2023, UN Secretary-General António Guterres warned that "Extreme weather is becoming the new normal" and urged countries to protect their people from the searing heat, fatal floods, storms, droughts, and raging fires that will surely follow.

Recent hazard events – including powerful and dangerous storms - have certainly been stronger than historical norms. They have often been stronger than many predicted. And they certainly provide disturbing insights into how the "new normal" might be.

This report asks how we can we learn from recent disasters? How can we protect more people when the next hazard hits? How can we reduce vulnerability and exposure to risks to minimize death and destruction and to avoid disasters?

The report applies 'forensic' disaster analysis to look at ten recent events, aiming to understand better the unique footprints - or disaster DNA - of these specific occasions. Forensic Investigations of Disasters (FORIN) aims to improve the understanding of disaster risk construction and disasters. It offers policy options and evidence-based recommendations for better corrective, as well as prospective approaches to integrate disaster risk reduction into development policy and processes. This involves identifying underlying causes, risk drivers, and entry points for decision making so that risks can be recognized, evaluated, and addressed.

In doing so, FORIN pinpoints key gaps in our adaptation to, and management of, more volatile and intense events. It also highlights cases where human decisions, including the continued burning of fossil fuels, are driving more and worse disasters.

On the brighter side, this report also shows how proactive risk reduction removes obstacles to sustainable development by reducing the impact of disasters and prevent them from escalating further By looking ahead at future trends, the report shows that good forensic analysis enables more targeted and effective risk reduction. It thus encourages all readers of this report to think about how they can apply a similar approach and learn from recent disasters too.

The ten case studies featured in this report produce several key observations:

- All case study countries now have disaster risk management legislation in place. They plan for disaster risk reduction and have invested to some extent in early warning systems.

- Investments in disaster risk management, especially at community level, are already saving lives. These investments are a key contributor to accelerated recovery when disasters occur. They protect lives and livelihoods alike. However, they need to be more targeted towards managing root causes and drivers of risk.

- However, in all cases studies reviewed, the work to build resilience is struggling to keep up with the growing scale of hazard impacts, because people and assets are still left vulnerable and exposed. This clear – and widening - resilience gap is costing lives and livelihoods.

- Where we do know how to prevent or reduce the disaster impact, the key challenge is not a lack of knowledge. Rather, it is a lack of focus and the inability to take the lessons from smaller disasters and apply them to larger, more dangerous events.

- Vulnerability, rooted in poverty and inequality, is perhaps the biggest indicator of disaster risk and impacts.

- Other major contributors include land degradation and land use changes, inefficient water use, and failure to enforce legislation on the environment and disaster risk reduction. Disasters have stronger impacts when multiple hazards combine, impacting people, but also the environment and economy.

- Unplanned urbanisation and risk-blind land use planning as well as the deterioration of biodiversity in and around urban areas are frequently recurring themes, while the development and implementation of construction standards often plays a role in defining the scale and intensity of any impacts.

- Multiple case studies highlight low cost, low regret actions to benefit simultaneously people, planet, and prosperity. Such actions include maintaining waterways to prevent them from clogging during floods or investing in early warning and evacuation plans.

- The report case studies show how many larger disasters are trans-boundary. This insight underscores the need for more integrated thinking about the impacts on people, planet and prosperity.

- Finally, existing financial mechanisms for disaster risk management are too basic. Risk transfer tools such as insurance may be available, but often they are either voluntary or unaffordable. They cover just a tiny percentage of the world's financial disaster risk. Disasters keep happening, but too often governments do not have the finance to react. Too often, they are unprepared.

Our generation has a responsibility to deliver a more resilient future. This requires us to shift from short-term responses to decision making processes that are long-term, sustainable, and risk-informed.

Risk reduction and long-term planning must connect with the public and private sectors.

Disaster Forensics Approach

Source: UNDRR, 2024

Part 2: Why learn from past disasters?

The increased frequency and intensity of hazard events around the world confirms what the IPCC's Sixth Assessment Report (AR6) report already told us: As global warming climbs beyond 1.5°C (2.7°F), the world faces a new and unprecedented level of climate hazards.

As the scale and intensity of these climate hazards increase, the lack of preparation means that they are more likely to become disasters. Hunger, poverty, health risks and unsafe land use, rapid and unplanned urbanization all increase the risk, while – in the short-term - the current El Nino cycle adds to the danger. In a connected world risk can combine with - or compound – with other factors such as the El Nino cycles to slow or even reverse socioeconomic development, exacerbate social tensions, instability, and economic insecurity as well as increase humanitarian needs. People's lives get worse.

Hazard events are more likely to become disasters when people, assets, or ecosystems are exposed and vulnerable. Unsustainable development, including inequalities, increases exposure and vulnerability, building the risks of compounding or cascading impacts, as well as polycrises. The challenge for all countries, especially those with high levels of disaster risk, is to build resilience.

Disasters are rarely unique. Often, they are preceded by events, which are smaller but very similar. It is only the magnitude of the disaster which changes. By examining such events in detail, however, we can learn about their underlying drivers and search for effective solutions. The lessons learned could prevent much bigger disasters, and contribute to an inclusive, interconnected and financially stable future.

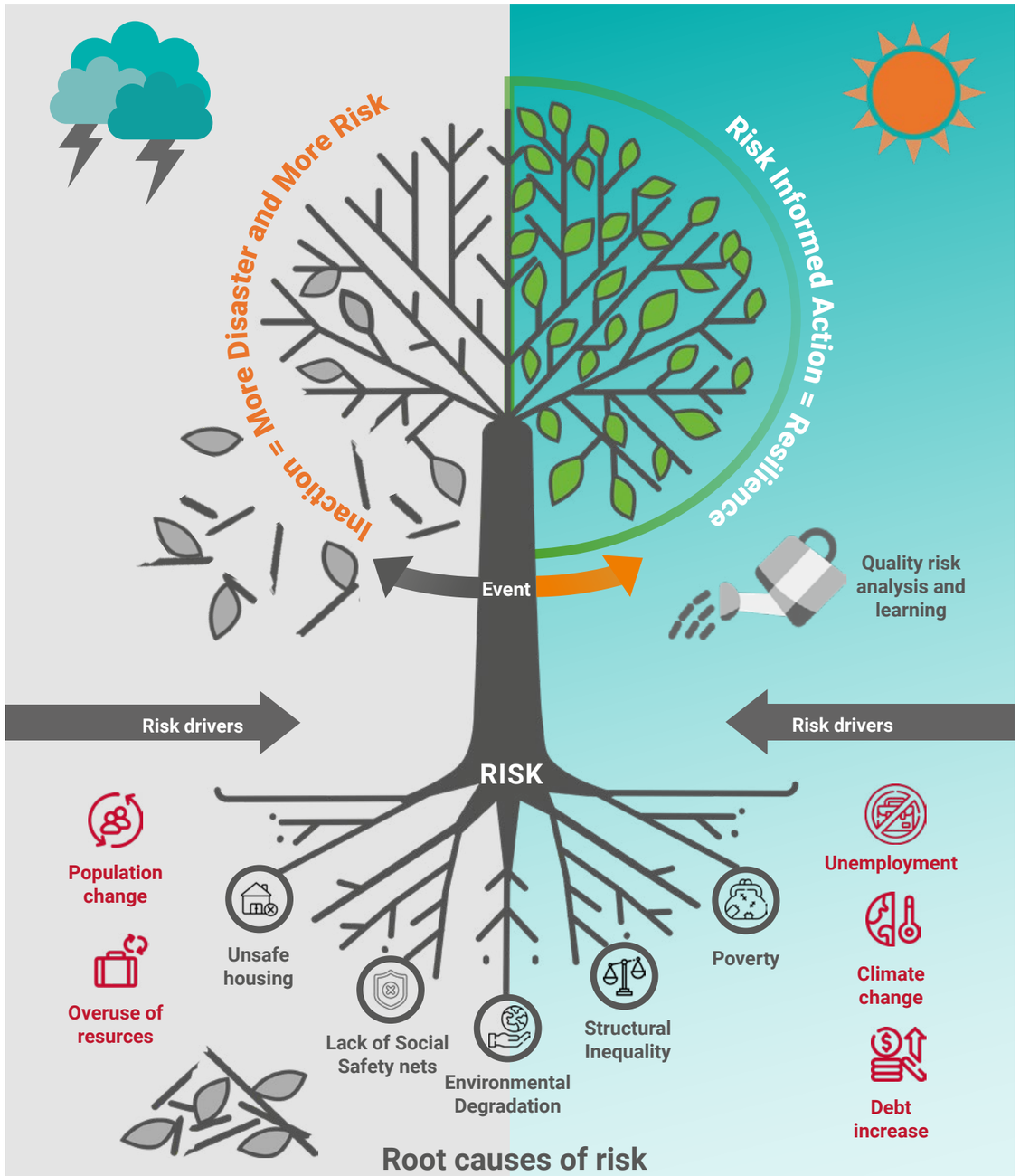
This report looks at the Forensic Investigations of Disasters (FORIN) and Disasters Avoided Methodologies, as well as the importance of establishing a multi-disciplinary process for learning from disasters. In an ideal world, this learning will replace the casting of blame.

It then provides 10 case studies, each one with a forensic risk analysis, which systematically examines and investigates the disasters to understand their causes and impacts, as well as the effectiveness of any mitigation measures. The approach aims to improve future risk management by identifying the lessons from previous disasters. In some cases, the mitigations have been so effective that disaster has been avoided altogether.

Each of the case studies also looks forward at key including demography, urbanisation or land use that may affect future risk. They provide insights on the lessons learned and potential actions in each case.

Indeed, a core theme of this report is that countries and policy makers should learn from the past to improve their future. In a world of accelerating climate change, this approach becomes even more important.

The choice between the pathway to resilience or the pathway to more risk and disaster



Source: Based on Oliver-Smith, A., Alcántara-Ayala, I., Burton, I. & Lavell, A., 2016, Forensic Investigations of Disasters (FORIN): A conceptual framework and guide to research (IRDR FORIN Publication No. 2), Integrated Research on Disaster Risk, Beijing. International Council of Scientific Unions, p. 56

Qacha Chalu Water Point, Dhebtiti Kabele, Fantale Woreda, East Shoa Zone, Ethiopia - the only water source for miles that people need to travel to

Source: UNICEF Ethiopia, 2016, Ayene

Part 3: How forensic analysis can help

By studying the relationship between hazards, risk, and disasters, we can better understand how to reduce disaster risk in a way that prevents the next hazards from becoming disastrous.

However, identifying key drivers and root causes of disaster is difficult when examining large, intensive disasters in major cities or areas that are densely populated and economically dynamic. Risks take time to build or accumulate, connecting with other risks and factors.

The FORIN methodology helps to simplify the process of studying disasters and shine a light on insights that may one day save many lives. It has several features which help to improve the understanding of disaster risk, offering policy options and other evidence-based recommendations that can be integrated with development policy and processes to reduce the risk of disaster.

Rather than examining just the immediate triggers, for example, the methodology seeks to identify the root causes of disaster looking at historical, social, economic, political, and other factors too. It integrates insights from various disciplines, including social sciences, natural sciences, and public policy to provide a more holistic view, helping to understand the complex interactions between different factors that lead to the disasters.

The method thus places significant emphasis on understanding how different populations are vulnerable to disasters and what factors contribute to – or hinder – their resilience. It requires the study of governance structures, socioeconomic conditions, infrastructure, and community preparedness. It examines the role of governance and policy in disaster risk reduction, looking at how policies, laws, and regulations either contribute to or mitigate disaster risk. The FORIN methodology advocates for more proactive and preventive approaches, rather than reactive responses.

The FORIN approach thus differs from other post-disaster assessments, such as Post-Disaster Needs Assessments, which focus on quantifying needs and guiding responses. Unlike some post-disaster evaluations that aim to assign blame for mistakes or missed opportunities, a disaster forensic study highlights opportunities for future action and pre-emptive risk reduction. The FORIN methodology looks at past disasters with the aim of learning and understanding, however complex that may be.

BOX 1:
Forensic Analysis

The following questions outline a simplified questionnaire for conducting a forensic analysis of any disaster. The questions follow the three key steps used in the FORIN methodology.

STEP 1 – UNDERSTANDING THE DISASTER DNA

Analyze the specific hazard, exposure and vulnerability factors that made this disaster unique and significant. This involves a descriptive analysis of hazard, exposure, unsafe conditions and subsequent patterns of damage, loss and impact

What happened? (Hazard)

- What triggered the event?
- Did the primary event lead to related secondary events? For example, did the earthquake cause landslides or dam failures which resulted in flooding?

Where was the damage concentrated? (Exposure)

- How were social and environmental elements exposed?
- How has the exposure evolved over time and space in relation to planned or unplanned development and physical threats?
- Were zoning regulations, land use controls and infrastructural codes adequate for existing risk levels in different areas?
- Were changes in exposure levels due to social decisions on location or changes to the physical environment? What was the role of deforestation, urban design and construction, or even climate change?
- What was the social and economic structure of the exposed communities?
- How were loss and damage distributed across different areas, social groups, and types of infrastructure?

- What factors influenced territorial expansion? Were the safer areas occupied before the more hazard-prone areas?
- Did environmental laws and norms address hazard and vulnerability concerns?
- Was there a clear relationship between exposure to hazards and poverty levels? How did chronic risk factors (unemployment, poor health, drug addiction, or personal and social violence) increase disaster risk and impact?
- Does appropriate legislation exist at national and local levels, including building codes, enforcement and specificity on risk management issues?
- Is insurance available for loss or liability? Is it required?
- Was Disaster Risk Management (DRM) integrated into other policy areas such as urban planning, environmental management, and insurance?
- Are there research and educational capacities focusing on risk awareness and insurance cover?

Who suffered most and why? (vulnerability)

- How did past population growth and distribution contribute to the disaster?
- How did environmental degradation and depletion of ecosystem services play a role?
- What were the impacts of poverty and income distribution?

What was resilient?

- What were the institutional and governance elements that contributed to resilience?

Result of Step 1 = Identification of the key DNA strands (unique inflection points) that made this disaster unique. The inclusion of disaster narratives and conversations with impacted people can deepen the analysis and provide a reality check for proposed risk reduction actions.

STEP 2 – FUTURE TRENDS

Look deeper at the identified key areas of disaster DNA and predict potential future trends up to 2050. For example, if urbanization and informal settlements were major contributors to flood damage, then what are the current and likely future trends for urbanization and informal settlements?

Result of Step 2 = Conduct a future foresight analysis to identify which areas of current risk are likely to increase in the future.

STEP 3 – FORENSIC LEARNING

Facilitate a multi-stakeholder discussion to review and refine the analysis, co-creating potential policy and practical actions to reduce the risk associated with each identified DNA strand, considering the disaster's impacts and future scenarios.

Source: Shutterstock

Part 4: Applying forensic analysis

This report presents ten case studies and their forensic investigations. Each of these case studies was written by a contributing author, who drafted a short analysis. The authors include risk management professionals, government and academics with extensive practical knowledge of the disasters considered.

To prepare their case studies, the authors used the FORIN methodology, which involves several key steps, including analysis of a disaster's essential characteristics, consideration of future trends including potential risks and how they might involve, as well as the lessons learned that can be applied for future disaster risk reduction. Within the FORIN methodology, these three steps are as follows: (1) Understanding the disaster DNA, (2) Considering future trends, and (3) Forensic learning and action.

In their analyses, therefore, the contributing authors outline the disaster itself, then explore factors which made the disaster more or less likely and severe. They look at policies and practice on land use and territorial planning, hazard-resistant building techniques, environmental management, and more, for example. They also look at contextual features such as socio-natural hazards, poverty reduction and socio-spatial segregation of territory and unsafe settlements. How do immigration and urbanization affect the risk of disaster? What governance issues have had an impact?

Guiding questions for the authors also aimed to identify the pre-emptive actions that helped to prevent a worse disaster. By distilling key elements of the FORIN approach, therefore, the report aims to inspire further refinement of the methodology, as well as adoption in other contexts. One key lesson from this exercise is that many practitioners need more and better capacity to use the FORIN methodology. This holds true in the public and private sectors, as well as for academia, and civil society. The benefits will be worth the effort.

Step One: Understanding the disaster DNA

A forensic analysis aims to uncover and understand the root causes and risk drivers that contribute to disasters. This comprehensive approach integrates various disciplines and actors, ensuring that all dimensions of disaster risk are considered, including environmental and socio-economic factors. By identifying these root causes, forensic investigations help to develop targeted strategies to enhance resilience.

The analysis focuses on the intensity, distribution, and impact of triggering events. Assessing pre-existing vulnerabilities, exposure conditions, and immediate causes of devastation provides critical insights for risk reduction and mitigation. Understanding how development processes contribute to disaster risk is crucial, underscoring the importance of sustainable development for disaster risk reduction. This involves analysing population dynamics, territorial expansion, and ensuring safe and sustainable land use. The effectiveness of zoning regulations, land use controls, and infrastructural codes is also examined, along with the role of socio-economic structures, poverty, and environmental degradation in contributing to disaster risk.

A key element of the forensic approach is “learning by doing”. For example, in this report’s desk study analyses, author groups from different technical and stakeholder backgrounds developed insights through conversations and collaboration. In some cases, technical counterparts had to reach out to unfamiliar departments to gather information and place their expertise in a broader context of the event.

High-quality case studies from forensic investigations are disseminated widely to guide and inform. These investigations also build the capacity of young researchers and local institutions. Engaging various departments, including health authorities, meteorological institutes, land management or land use services, and civil protection authorities is recommended. Additionally, regional and national technical agencies, as well as international and local non-governmental organizations, should be involved.

A key lesson from the drafting process was the tendency to focus too much on describing the hazard event and direct exposure, rather than understanding the pre-existing or emerging vulnerabilities that led to extreme impacts and losses. There was also a tendency to focus on response elements rather than taking a more holistic view of the underlying risks and drivers.

Step Two: Considering future trends

This report uses a forensic approach that focused on identifying where resilience has already been built and where disasters have been at least partially avoided. Experts were also asked to look forward and assess current future trends in key areas of exposure and vulnerability.

The case studies in this report provide both experience and inspiration, while also indicating how much is still to be done. Closing these significant gaps will require knowledge and experience. Disaster avoidance is a continuous process that involves monitoring and assessing all six points in the model to improve their implementation. Successes should be shared and celebrated, reinforcing each other and supporting narratives about disasters that were prevented through proactive efforts, saving lives, and supporting livelihoods.

The second part of the report focuses on specific elements of the “disaster DNA” and engages experts to explore potential future trends and opportunities for risk reduction. The goal is not to consider every possible future but to focus on the “DNA strands” that are currently increasing risk and to identify actions that could prevent future impacts.

Furthermore, each case study highlights factors from the Disasters Avoided Model and their relevance to disaster risk reduction.[1]

1 Byatt et al., 2024

Step Three: Forensic learning and action

The analysis in parts one and two served as the foundation for the “learning from the past to assess the future” chart in part 3. In a country-specific process, this third step could be further developed to offer practical, alternative solutions for enhancing disaster risk reduction strategies. Quality analysis in this form provides robust, evidence-based policy recommendations, bridging the gap between academic research and practical policymaking. Insights from these investigations inform policies grounded in thorough research and real-world evidence.

Source: Shutterstock

Part 5: Ten case studies

In Ethiopia's Somali region near Hargele, thousands of displaced women and children face dire conditions due to severe drought

Source: UNICEF Ethiopia, 2023, Mulugeta Ayene

Mexico Earthquake / 2017

Case Studies No 1

Earthquake damage on an apartment buiding in Mexico City.

Source: Shutterstock

STEP 1: Understanding the disaster DNA

What Happened?

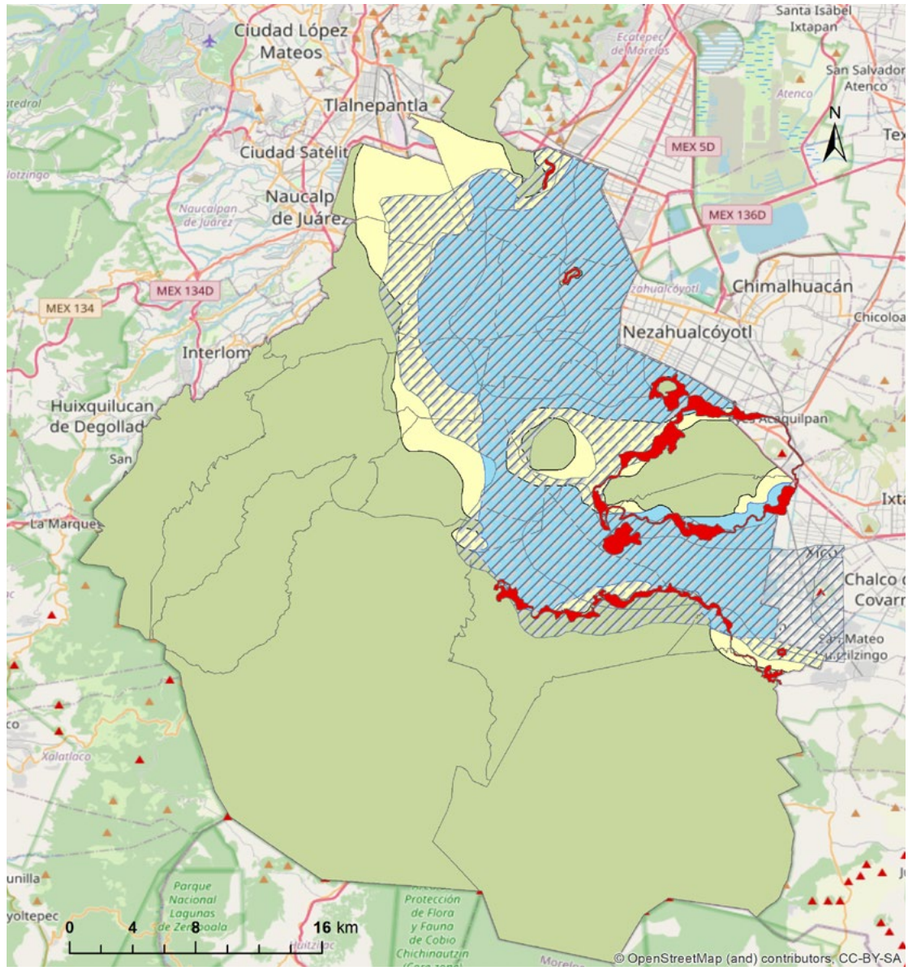
On September 19, 2017, in the middle of the day, an intraplate earthquake happened about 120 km from Mexico City at a depth of 57 km. Intraplate earthquakes are less common than other types but have occurred in Mexico City since the 1970s. One feature of these earthquakes is that the trembling intensifies as the seismic waves propagate further from the epicentre.

The earthquake, with a magnitude of 7.1, toppled dozens of buildings and damaged hundreds more. At least 326 people died, including 187 in Mexico City. Thousands of volunteers helped rescue workers day and night, using buckets, shopping trolleys, and wheelbarrows to shift tonnes of debris in the search for survivors.[2]

2 Webber, 2017

The earthquake showed how effective regulation and other measures can significantly reduce the levels of death and destruction, however. The 2017 mortality rate was significantly lower than for a 1985 earthquake which killed somewhere between 10,000 and 30,000 people. The economic damage was also less severe. While the 1985 earthquake caused damage worth $4.103 billion today (2.7 percent of GDP), losses from the 2017 earthquake were valued at $2.476 billion (0.15 percent of GDP).

Figure 1. **A significant zone of CDMX is under the ancient lakebed. This presents a complex set of challenges as the soft clays beneath leads to uneven ground settlement that damages buildings and infrastructure**



Source: Government of Mexico City and Secretariat for Comprehensive Risk Management and Civil Protection.

The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

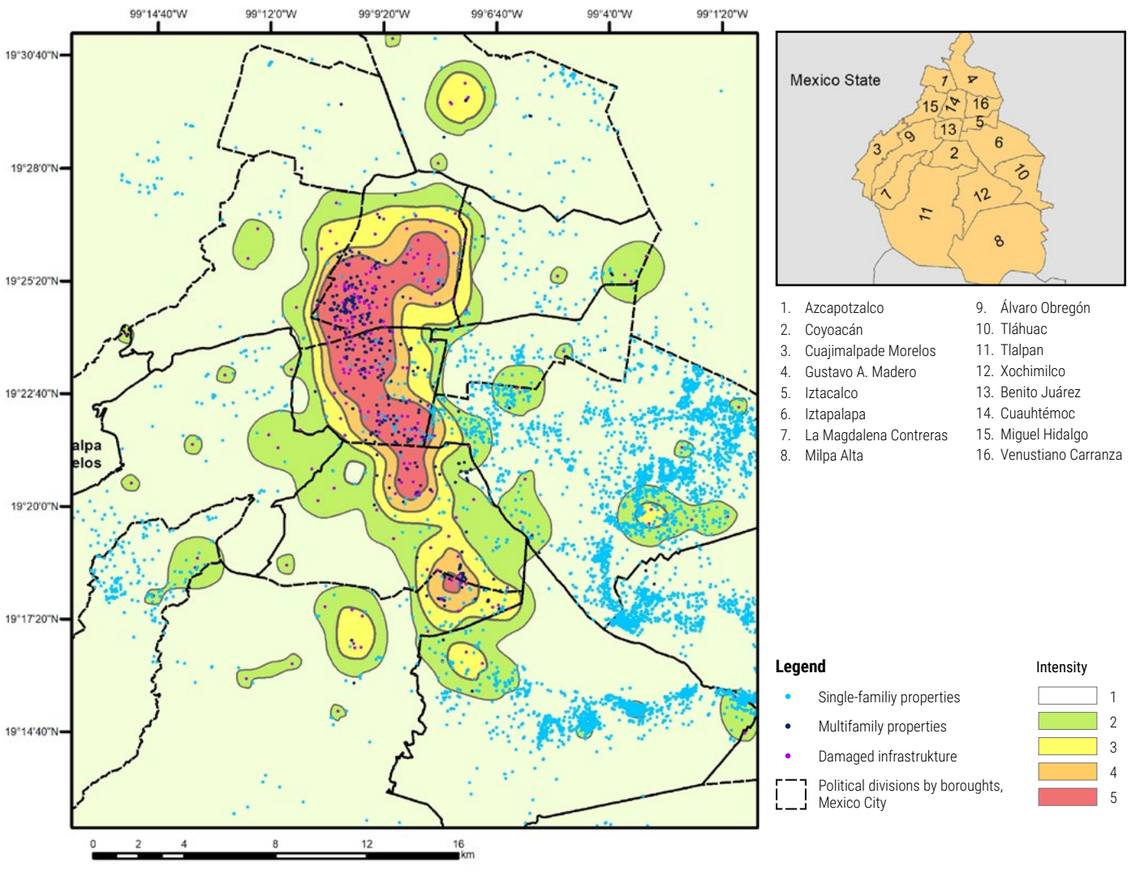
Exposure: Where was damage concentrated?

The population of Mexico City fluctuated from 8.8 million in 1980 down to 8.2 million in 1990, then back up to 9.2 million in 2020. Many people live in risk-prone areas on the city's outskirts and commute daily to the city centre.

The 2017 earthquake impacted single-family homes more than public infrastructure. Most residential neighbourhoods near the city centre were damaged, affecting working- and middle-class families the most. Many multi-story buildings collapsed, while more than 20,000 homes, schools, and hospitals were damaged.

Most of the buildings that collapsed were built before the 1987 building code. Collapse factors included inadequate structural support such as concrete columns without steel reinforcements, construction on soft soils, and land subsidence linked to intensive aquifer exploitation. Urban design and construction were also contributing factors.

Figure 2. The intensity of the 2017 earthquake was concentrated in the city centre, where most of the earthquake-resistant buildings are located and the population density is low, compared to other areas of the city



Source: Government of Mexico City (2018), Secretariat for Comprehensive Risk Management and Civil Protection. "*Damage and Intensity of the 2017 Earthquake*".

The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Vulnerability: Who was affected and why?

Despite Mexico City's wealth, around 27.5 percent of its population lives in poverty, with significant income inequality. Many residents work informally, including street vendors and small business owners. These workers often receive low wages and have limited access to formal employment.

Insurance to protect against earthquake losses is rare. Mexico City's Ministry of Finance provides earthquake insurance for public buildings, but high housing costs and gentrification prevent the general population from purchasing it.

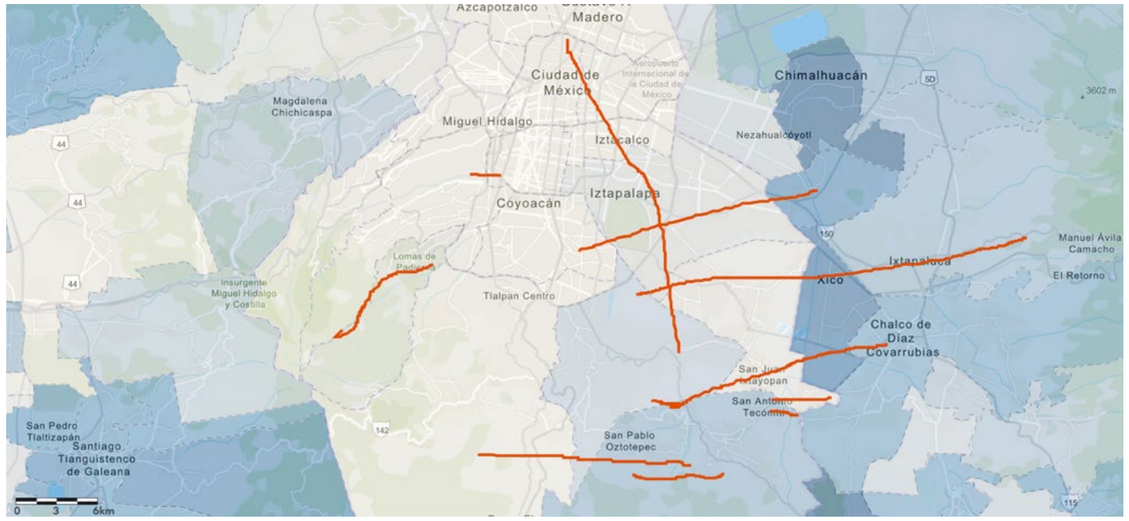
In Mexico, 34.8 percent of owned homes are in an irregular situation, meaning they lack deeds, are not in the owner's name, or the owner is unknown. In Mexico City, 337,545 homes (23.6 percent of the total) are irregular. Some 83,601 are registered under someone else's name, and 246,283 lack deeds.[3]

Rebuilding in a Mexico City neighbourhood badly hit by the earthquake of 2017

Source: Flickr/Carl Campbell (CC BY-ND 2.0)

3 Villalobos, 2022

Figure 3. **The geological faults beneath Mexico City intersect with communities with significant levels of monetary poverty, such as Xico, Ixtapaluca, Chalco de Díaz, and San Pablo Oztotepec**



Source: UNDRR based on the The National Council for the Evaluation of Social Development Policy data – CONAVAL. 2023

The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Resilience: what factors limited the impacts?

Several factors likely contributed to the lower death toll in 2017, including the quake's occurrence in the middle of the day when many workers were in the city centre. Despite fewer casualties, the economic impact on poor households was considerable, however.

The situation highlights the importance of good governance. Mexico City's building codes, a central aspect of good governance, have improved over time, requiring buildings to be earthquake-resilient. Governance at both national and city levels contribute to societal resilience.

However, the city's growing population increases earthquake vulnerability. Analysing earthquake risks and events is crucial for better physical and social resilience. Good governance ensures the implementation of effective city-wide physical and societal earthquake resilience. It enables Mexico and other countries to prevent earthquakes from becoming disasters.

Mexico City's building code has evolved significantly since its creation in 1920. Seismic design regulations were introduced after the 1957 earthquake, with further requirements added in 1966 and 1976. An earthquake in 1985 led to significant revisions in 1987, 2004 and 2022. When the 2017 earthquake struck, the 2004 code was in effect.

The 1985 earthquake affected buildings on long-period deposits of the lakebed zone. Post-1985, new institutions were created, such as the National Civil Protection System, the National Disaster Prevention Centre and the Seismic Instrumentation and Registration Centre. Regulations and construction standards were updated, information campaigns were launched, and earthquake drills became common practice.

The 2017 earthquake caused more damage to low- and medium-rise buildings than the 1985 earthquake, particularly in the transition zone. Following the 2017 earthquake, Mexico City established the Integrated Risk Management and Civil Protection System and passed the Law on Integrated Risk Management and Civil Protection, which has been updated since.

Effective land-use planning is crucial for minimizing disaster risks. Mexico City must enforce zoning laws and regulations to ensure new developments are constructed in safe areas while protecting existing infrastructure and the environment.

Integrated disaster risk management requires sustained effort. Mexico City should continue conducting thorough risk assessments to detect potential hazards, vulnerabilities, and exposure levels. A collaborative approach is essential, involving local government, science and technology communities, residents, youth, women, businesses, and civil society organizations.

STEP 2: Future trends

People

- Over the next decade, the population in Mexico City's outskirts is expected to grow by an average 1.1 percent per year.[4] This growth will likely lead to an increase in informal housing construction for the poor, accompanied by unstable or poorly planned infrastructure such as aqueducts and pipelines.

- Following the 2017 earthquake, an insurance scheme was developed between Swiss Re and the Mexico City government. This scheme protects the city government from losses exceeding its own disaster fund for earthquakes with a magnitude of 8.5 or more. The insurance automatically covers homeowners who meet specific requirements, such as having fully paid their property taxes at the time of the event. This creates a strong incentive for tax compliance, boosting the city's revenues. Together, the insurance solution and the additional revenue will help Mexico City reduce the protection gap associated with major earthquakes. However, informal settlements are not covered by this scheme.[5]

Planet

- Construction in hillside areas without proper risk control and environmental permits could lead to landslides during earthquakes.

- Excessive groundwater extraction in informal settlements jeopardizes the safety of the land where these homes are built.

- In addition to the seismic risk, rapid urban growth is draining groundwater more quickly than it can be replenished. The depletion of subterranean aquifers causes subsidence and massive sinkholes in the city's eastern boroughs such as Iztapalapa, Xochimilco and Tlahuac. Hundreds of houses in these boroughs were damaged on September 19, 2017, when the porous soil under them shifted. With a warming planet the overuse of water resources will likely increase.[6]

Prosperity

- Approximately 2.5 million workers in Mexico City reside in informal settlements within high seismic risk zones.[7] This situation could significantly impact the city's economy, as these workers represent around 47 percent of the total workforce in Mexico City.[8]

- Considering the economic losses related to internal displacement of the employed population of internally displaced persons, Mexico lost an estimated $160 million in economic production due to the September 2017 earthquake.[9]

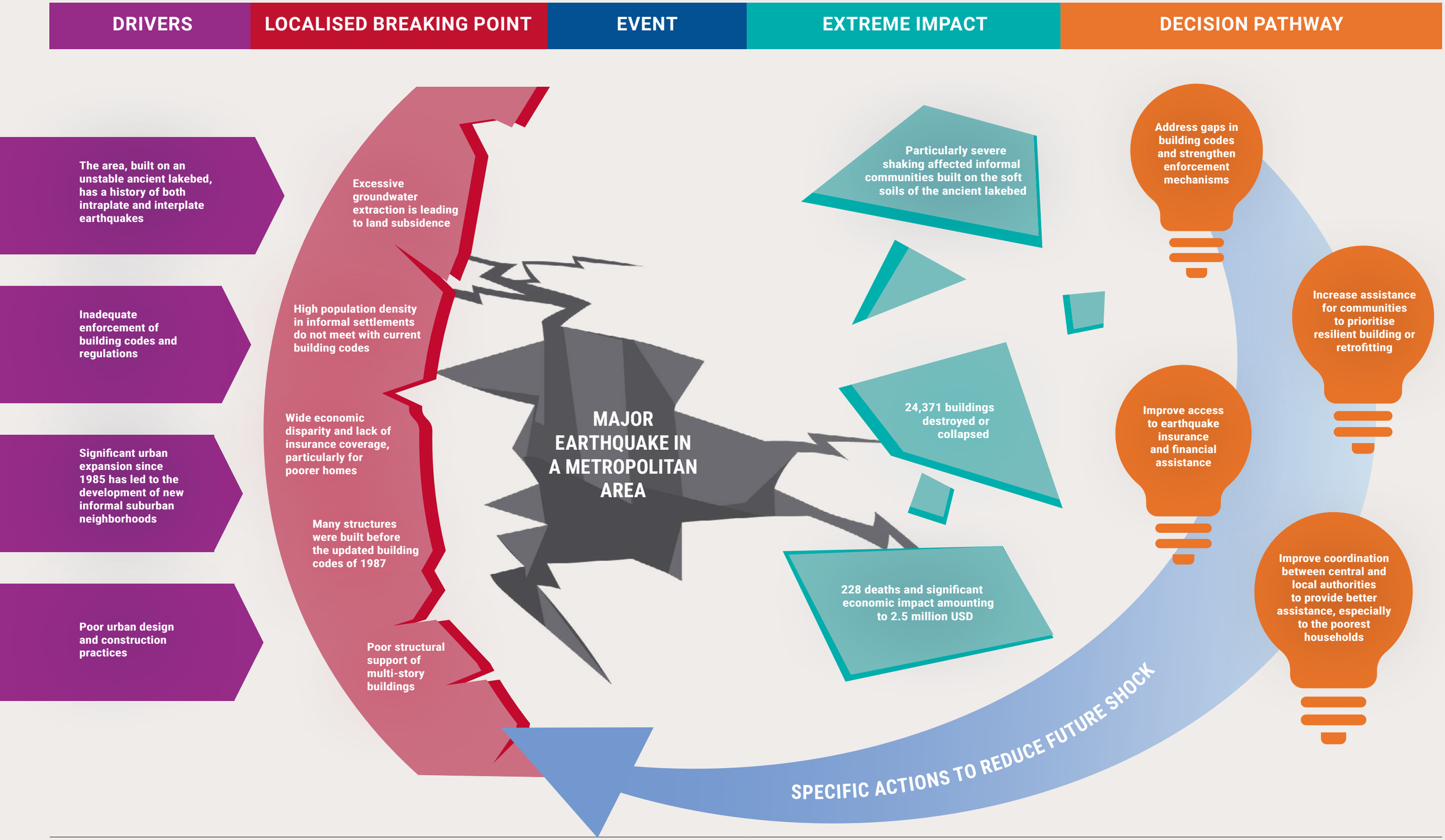
4 UN Habitat, 2018
5 Swiss Re, 2019
6 Pskowski, 2018
7 Jean-Baptiste et al. 2018
8 ILO, "Informal employment in Mexico: Current situation, policies and Challenges"
9 IDMC, 2019

STEP 3: Forensic learning

This section aims to encourage dialogue around the forensic analysis to foster improved decision making. The areas for consideration below are envisaged as an input to stimulate in-country discussion and action plan on future disaster prevention and enhanced disaster risk management.

	People	Planet	Prosperity
Learning from the past	Mexico City has regularly updated its building codes since the 1985 earthquake. This has helped to reduce building collapses during seismic events. Implementation of earthquake drills and public awareness campaigns has prepared residents for seismic events, improving their response during disasters. Risk communication and EW have improved, but large parts of the population do not adequately understand the information. This leaves them vulnerable in case of emergency Enhanced training programs for emergency responders have improved disaster response operations and coordination.	Regular monitoring of environmental changes, such as subsidence and soil stability, has been crucial in predicting and mitigating earthquake damage. Excessive extraction of groundwater has contributed to land subsidence, exacerbating the impacts of earthquakes.	While public buildings are covered by insurance the coverage of residential housing is far less covered by insurance. Many residential buildings occupied by poorer people around the city centre are considered “informal”. They do not adhere to building codes. They do not have insurance. Development of economic recovery frameworks post-earthquake has facilitated quicker rebuilding and economic stabilization. Provision of earthquake insurance for public buildings has been a crucial financial safety net, enabling quicker repairs and reconstruction. Investments in retrofitting older buildings and constructing new ones to high safety standards have minimized earthquake damage and losses. However, lack of control and regulation over informal buildings where poor people live has increased their vulnerability to earthquake damage and casualties.
Resilient features	Improved building codes and construction standards reduced building collapses during the earthquake. Public awareness campaigns and regular drills enhanced community preparedness and response. Strong community networks and volunteer groups facilitated immediate rescue efforts. Lack of government control over informal buildings where poor people live increased vulnerability. High poverty rates and income inequality exacerbated the impact of the earthquake on marginalized communities.	Soil stability monitoring helped predict areas at risk, aiding mitigation efforts. Green spaces and parks provided emergency assembly points and reduced urban heat. Excessive extraction of groundwater in informal settlements jeopardized the safety of the land where housing is located. Insufficient land-use planning allowed for construction in high-risk areas prone to landslides and flooding.	Retrofitting of older buildings reduced damage, emphasizing long-term resilience investment. Economic recovery frameworks facilitated rapid stabilization of the local economy. Informal economy workers lacked social protection and faced significant economic losses. Delayed restoration of critical infrastructure hampered economic recovery efforts.
Actions from the present for the future	Understand the alert system and stay informed about early warning signals. Enhance consciousness about building codes and ensure that any property purchased or built complies with seismic safety standards. This will minimize earthquake damage. Avoid informal self-construction and promote strict adherence to building regulations.	Implement rapid solutions to ensure access to drinking water in informal communities. Replace old water systems drainage and implement innovative solutions in new informal settlements. Create legislation on proper management of disaster material Monitor and track new informal constructions in non-urbanized areas with high environmental disaster risks. Generate policies for relocation and access to housing or economic policies.	Implement social and monetary assistance for improving constructions / housing assistance in informal areas without earthquake building codes. Generate economic policies that promote wealth generation outside of large urban centres and reduce internal migration. Conceptualize a comprehensive land use plan that promotes comprehensive economic and social development for Mexico City and its surrounding provinces, accompanied by measures to integrate different municipal bodies.

Mexico Earthquake / 2017



Case Studies No 2

Horn of Africa Floods and Drought / 2020-2023

Step 1 – Understanding the disaster DNA

What Happened?

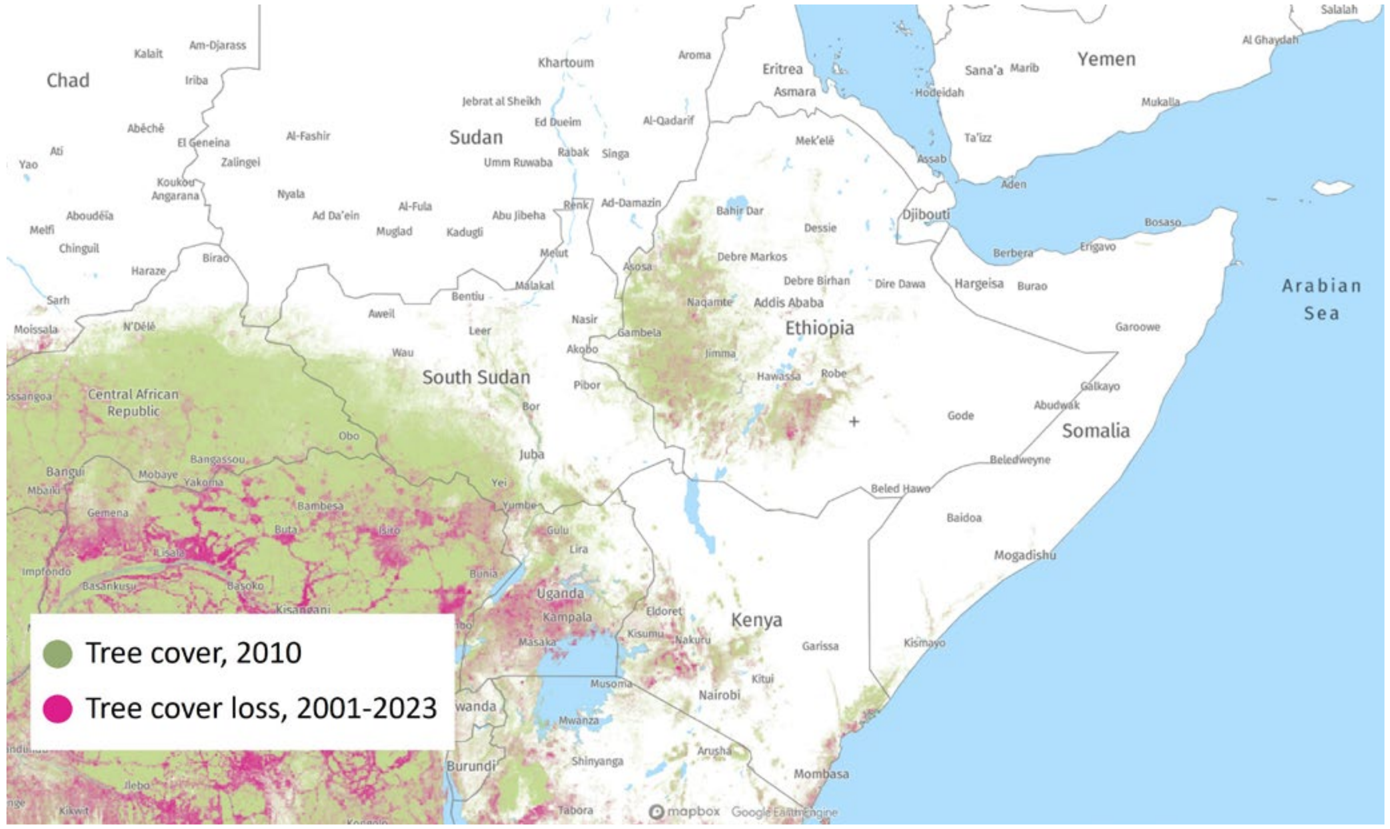
The eastern Horn of Africa is currently experiencing increasingly intense and recurrent cycles of flooding and drought. Across Ethiopia, Kenya and Somalia, the 2020-2022 La Niña event was the most severe in 70 years due to its high intensity and its three-year duration, leading to at least four consecutive failed rainfall seasons. The region experienced extreme rains in 2019-20, followed by widespread and devastating floods, then a drought from 2020 to 2023, and severe flooding in 2023-2024.

Since 2010, the eastern Horn has experienced 8 failed rainy seasons, 5 average seasons, and 3 wet seasons, all linked to predictable oceanic influences such as the El Niño-Southern Oscillation (ENSO), Western V Gradient (WVG) and Indian Ocean Dipole (IOD). Climate change is increasing the frequency of these climate drivers and amplifying their effects, leading to recurrent catastrophic rainfall and record temperatures that severely impact climate-sensitive sectors such as agriculture, water resources, and health.

Environmental degradation is reducing the region's capacity to withstand extreme weather events, exacerbated by factors such as deforestation and land degradation. For example, in Somalia, moderate environmental degradation impacts 49 percent of the land, while severe degradation affects 30 percent.[10]

10 Green Somali Initiative, "*Sustainable Future: Horn of Africa*"

Figure 4. The region's deforestation and land degradation increase its vulnerability to extreme weather



Source: Global Forest Watch (GFW)

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Exposure: Where was the damage concentrated?

While climate-driven hazard events trigger shocks, underlying social factors such as deforestation, migration, urbanization patterns, and indebtedness contribute to increased exposure. Over the three-year period from 2020 to 2022, more than 30 million people across Ethiopia, Kenya, and Somalia faced drought-related food insecurity.

The direct impacts of reduced crop and livestock production were worsened by protracted conflict, adverse macroeconomic shocks, and limited coping capacity.[11]

In 2023/24, the worst flood-affected populations were mainly in densely populated urban and riverine areas of Somalia, Kenya and parts of Ethiopia. The effects of the multi-year 2020/23 drought were felt across East Africa, leading to significant food shortages regionally and globally, resulting in high food prices and hyper-inflation.

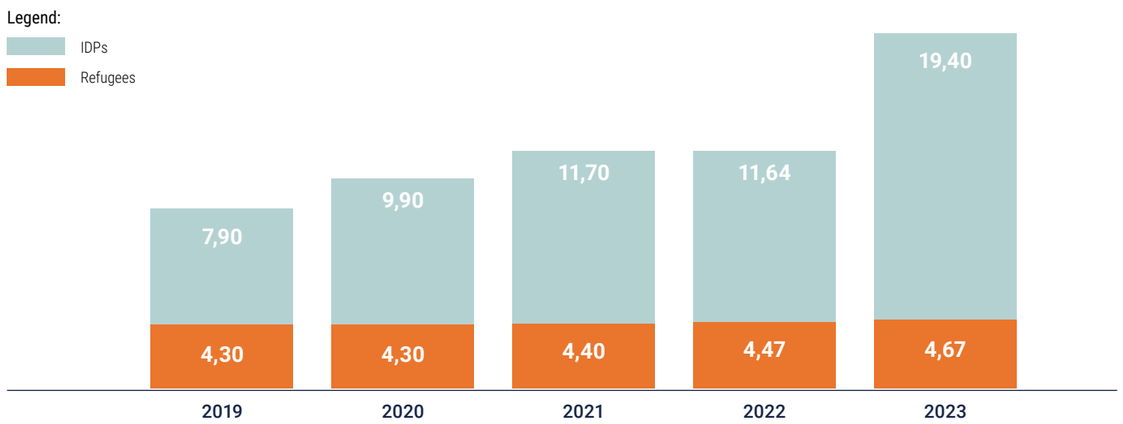
Urbanization is increasingly associated with the heightened impact of disasters in the region. Population growth in urban and peri-urban settlements often outpaces infrastructure and service development, increasing vulnerability to hazards. For example, in Kenya's Garissa County, 77 per cent of settlements reported the arrival of more than 205,000 people from other areas in search of goods and services to cope with the drought.

11 Global Forest Watch, "*Somalia: Forest Change*"

Drought Response Somali region, Afdher Zone. In Hargele IDP site, Afdher zone of the Somali region, many are staying near the town hoping to get support

Source: UNICEF Ethiopia, 2022, Mulugeta Ayene

Figure 5. **Although this trend had been emerging since 2020, between 2022 and 2024, a substantial increase of nearly 8 percentage points was recorded in the number of internally displaced persons (IDPs)**



Source: World Health Organization. March 2024

Table 1: **More than 29.9 million people are grappling with acute food insecurity at IPC3+ levels, with hunger intensifying in regions like Sudan, northern Ethiopia, and South Sudan**

IPC ANALYSIS (Projection period)	**Asseased Population**	**Crisis (IPC Phase 3)**	**Emergency (IPC Phase 4)**	**Catastrophe (IPC Phase 5)**	**(IPC Phase 4)**	**IPC 3+ as % of assessed Pop**
Djibouti (Jul - Dec 23)	1,181,675	185.312	100,102	0	285,414	24%
Kenya (Oct 23 - Jan 24)	16,617,000	1,258,750	265,600	0	1,524,350	9%
Somalia (Oct 23 - Dec 23)	16,955,266	3,280,770	1,014,100	0	4,294,870	25%
South Sudan (Dec 23 - March 24)	12,613,120	4,040,000	1,713,000	25,000	5,778,000	45%
Sudan (Oct 23 - Feb 24)	48,190,706	12,828,396	4,868,436,486	0	17,726,881	37%
Uganda / Karamoja (Sep 23 - Ferb 24)	1,285,000	293,150	48,440	0	341,500	27%
Sub-Total	**96,842,767**	**21,886,377**	**8,039,728**	**25,000**	**29,951,105**	
OTHER FOOD SECURITY ESTIMATES						
Ethiopia 2023	123,000,000	People in need of food assistance (Source HRP 2023)			20,100,000	16%
Total food insecure population in need of assistance IGAD Caseload					**50,051,105**	

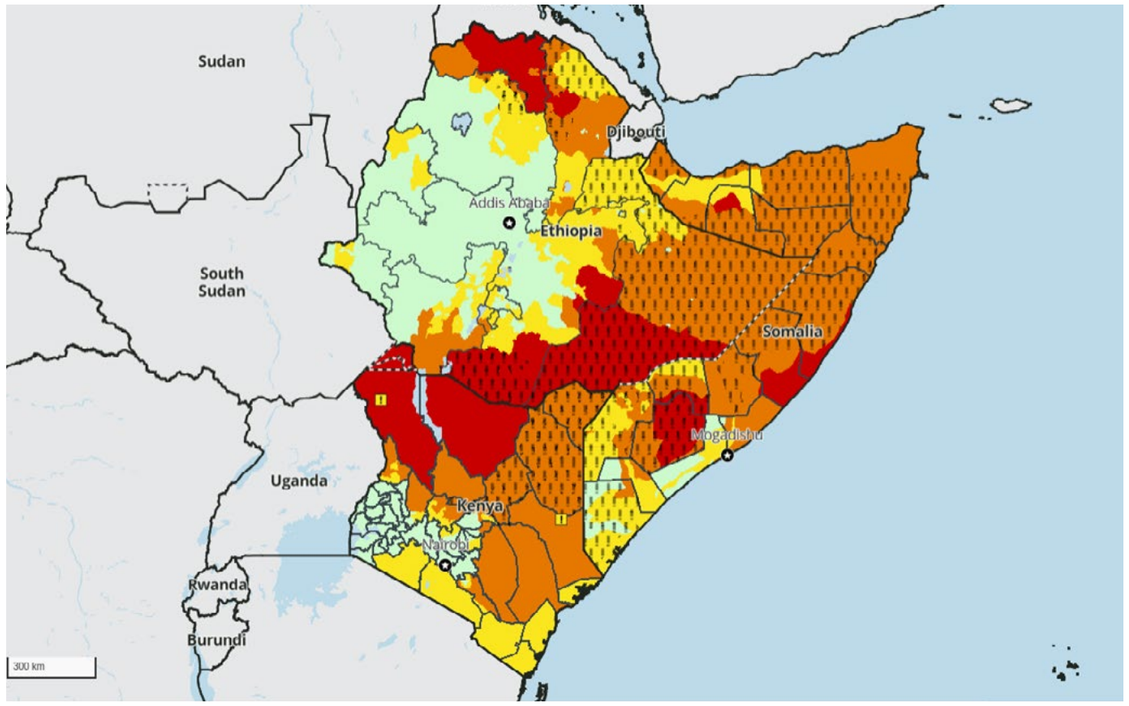
Source: World Health Organization. March 2024

Vulnerability: Who was affected and why?

Food insecurity in the Horn of Africa is a complex issue, deeply rooted in the region's pre-existing vulnerabilities such as chronic poverty and limited access to social and economic infrastructure. Poverty rates, defined as income of less than USD 2 per day, range from 16 to 50 percent, driven by both climate and non-climate factors.

Meanwhile, a significant portion of the rural population – 70 percent - is heavily dependent on climate-sensitive agricultural systems. Pastoral and marginal agro-pastoral communities are the most vulnerable. Since 2021, humanitarian appeals have urgently called for $ 2.4 billion to support 8.8 million people affected by drought in the Horn of Africa with monthly life-saving relief.

Figure 6. The HoA region has faced severe climate-related crises, including droughts and floods, leading to a significant increase in public health events and food insecurity. The drought has devastated livestock, crops, and livelihoods, particularly in rural areas



Source: Famine Early Warnings Network – FEWS net. 2023

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However, food insecurity is not solely driven by climatic events. Geopolitical factors such as cross-border and international trade bans on food commodities, high fuel and transportation costs, the global COVID-19 pandemic, and hyper-inflation, have all contributed to limiting food access in East Africa. Countries implementing food trade bans to safeguard their own food supplies have inadvertently exacerbated food shortages in regions dependent on imports.

For example, fuel prices have nearly doubled in some parts of East Africa compared to previous years (before 2023)[12], significantly inflating the cost of food distribution. This disruption has been compounded by hyper-inflation, which reached 15.5 percent by the end of 2023.[13]

In some countries, such as Ethiopia, inflationary pressures peaked at an average of 30 to 35 percent. Across the region, as much as one third of average cereal consumption is wheat or wheat products. Some 84 percent of this is imported, largely from Ukraine and Russia.[14] The cost of importing wheat has increased by 33 percent in Kenya.[15]

12 Kairu, "Case Study: The Horn of Africa"
13 BNP Paribas, 2023
14 IPES-Food, 2022
15 Ibid.

Vulnerabilities in the region vary due to several compounding factors:

- Weak Social Safety Nets: The lack of social support systems, limited access to education and healthcare, and discrimination exacerbate vulnerability for specific groups.
- Economic Fragility: Poverty, limited access to credit, and dependence on a single industry (tourism) can leave communities with few resources for recovery from shocks.
- Protracted Conflict: Ongoing political or resource-based conflict damages infrastructure, displaces communities, and disrupts access to essential services, further hindering resilience.
- Increased indebtedness: Rising living costs coupled with limited access to financial services can leave communities more exposed to economic shocks caused by extreme weather events.

East Africa has piloted both livestock and crop insurance programs, though their efficacy and impacts are not well documented. However, commercial farmers generally benefit more from such insurance due to the scale of loss in disastrous rainfall seasons. The 2020-23 food crisis was much worse for pastoral communities reliant on livestock than for commercial farmers with diversified income sources. Similarly, crop failures and limited reserves caused much greater hardship for subsistence farmers than for commercial farms with buffer stocks.

The drought had the following country-specific impacts:

- **Somalia**: The October 2022 drought affected 7.8 million people, equivalent to 46 percent of the country's population.[16]
- **Ethiopia**: The drought expanded to areas already affected by conflict, including the Afar, Oromia and Southern Nations, Nationalities, and Peoples' (SNNP) regions. Drought was a factor in the reported increase of child marriages in 2022 (264 percent in Somali, 69 percent in Oromia and 38 percent in SNNP regions).[17] Some 1.4 million children had their education disrupted by migration, school closure or sickness.[18]
- **Kenya**: An estimated 6.4 million people will require humanitarian assistance in 2023, including about 602,000 refugees, up 35 percent from 2022. This is Kenya's highest recorded number of people in need for at least 10 years. The drought has severely impacted communities' access to water, with nearly 95 percent of water pans drying up in 2022. People now have to trek between 8.6 and 17.6 kilometres to access water, an increase of at least 38 percent above the three-year average, the National Drought Management Agency says.[19]
- Moreover, an estimated 45,000 asylum seekers arrived in Kenya from neighbouring Somalia in 2022, according to UNHCR. In Kenya's Dadaab refugee camp, 46 percent of new arrivals interviewed cited the drought as one of the reasons for their flight. In nearby Kakuma, almost 20 per cent of new arrivals cited food insecurity, hunger, and drought as the reasons for flight from their countries of origin.

In Isiolo, Kenya, a new irrigation scheme is helping communities learn alternative methods to diversify income and become more resilient to recurring droughts.

Source: EU, ECHO, Martin Karimi

16 Centre for Humanitarian Data, "Somalia: The Current Crisis in Four Charts"
17 ReliefWeb, 2022
18 Ibid.
19 Humanitarian Action, 2023

Horn of Africa drought, the crisis at a glance

$ 3.7B	36.4M	27.4M	23M	23.8M	9.5M
Requirements	People affected	People Targeted	people in IPC3+ (drought related)	people living with daily household water insecurity	Livestock deaths

		Ethiopia	Kenya	Somalia
PEOPLE AFFECTED, TARGETED & REACHED	36.4M people affected	24.1M	4.5M	7.8M
	27.4M people targeted	17.1M 70%	59% 2.6M	97% 7.6M
	17.1M* people reached	56% 9.6M	36% 948K	86% 6.5M
DROUGHT APPEAL REQUIREMENTS & DROUGHT RESPONSE FUNDING**	$3.7B required in 2022	$1.7B	$290M	$1.8B
	$2.3B funded	52% $857M	55% $159.0M	72% $1.29B
FOOD INSECURITY & MALNUTRITION	23M people in crisis, emergency & catastrophe levels (IPC3+) (drought related)	11.9M**	4.4M	6.7M
	5.1M acutely malnourished children	2.7M	640.2K	1.8M
	1.3M acutely malnourished pregnant and lactating women	969.8K	111.6K	191.2K
INTERNAL DISPLACEMENT & SCHOOL DROPOUT	2.1M people internally displaced by the drought	590K	205K	1.27M
	3.2M at risk of school drop-outs	1.4M	54.5K	1.7M
LIVESTOCK DEATHS & WATER INSECURITY	9.5M livestock deaths	4M	2.5M	3M
	23.8M people living with daily household water insecurity	13M	4.4M	6.4M
DISEASES	13K suspected/reported cases of cholera	456	568	12K
	23.2K suspected/reported cases of measles	9.9K	212	13.1K

*People reached by ongoing drought response as of 30-Sep-2022. **This figure is the latest estimate of acutely food insecure people in Ethiopia (equivalent of IPC Phase 3+). It is based on analysis of relevant data, as part of the development of the Drought Response Plan, as there is no current IPC analysis for Ethiopia.

Sources: Horn of Africa Drought Regional Humanitarian Overview & Call to Action, 28 November 2022, IPC, FSNWG, UNICEF, UNHCR, IOM, FAO, WFP, OCHA and WHO

Resilience: what factors limited the impacts?

Environmental challenges in the Horn of Africa – including extreme weather events, rising temperatures, and unusual rates of plant die-offs – are significant concerns. However, positive developments include the integration of re-greening initiatives and other environmental projects. One notable example is the Great Green Wall Initiative, launched by the European Union, African Union, and others. In Ethiopia alone, the initiative has restored 151,448 hectares of land and trained over 62,759 people in food and energy security.[20]

Advances in long-lead forecasting and scenario development for climate-sensitive hazards are also noteworthy. However, there remains a gap between the development of knowledge and its translation into public awareness and long-term planning.

From a policy perspective, gaps exist between zoning regulations/codes and their effectiveness. Regulations might exist, but their implementation is often hindered by limited understanding at various government levels and weak enforcement. Discussions with regional experts revealed two primary concerns:

- Limited awareness and enforcement: Many stakeholders may not be fully aware of existing policies, or enforcement mechanisms may be weak.
- Focus on short-term solutions: Disaster management strategies often prioritize immediate response over long-term resilience building and risk reduction.

The lack of easily accessible and comprehensive disaster data also hampers long-term planning. Effective data collection and sharing, supported by appropriate legislation, are essential for informed decision-making and mitigating future disasters. In many cases, livestock censuses, crop production statistics, and health-related data are either lacking or outdated.

Countries in the Horn of Africa have diverse levels of early warning and disaster management institutions. Kenya and Ethiopia, for example, have robust multi-agency collaborative teams at both national and sub-national levels. These teams integrate sectoral climate information into their pre- and post-season contingency and response plans. Similar cooperation exists among the Intergovernmental Authority on Development (IGAD) and East African Community (EAC) Member States to build resilience to shocks. However, there is often a weak link between early warning and timely response due to limited funding, lack of decision- and policy-making information or competing priorities for limited national resources and political exigencies.

Research centres in agriculture, water resources, and health have highly skilled human resources at both national and regional levels. However, local funding is insufficient for research into climate adaptation and the rollout of solutions such as drought-resistant seeds. Most leading research centres are internationally funded, serving other commercial interests.

National and local governments are not always able to systematically address risks in their day-to-day policies and plans. Systems are still event-centric, focusing on response to events rather than addressing root causes and vulnerabilities. Effective risk management requires a mix of strategies and policy prescriptions, targeting deficiencies in social policies and environmental sustainability over multiple budget cycles.

Most IGAD and EAC member states have national agencies to manage the environment, but regulation and implementation remain significant challenges, linked to vested political and commercial interests, as well as structural corruption at all levels.

While tools like insurance have value, the vulnerability of pastoralists and marginal mixed-farming agriculturalists will require a combination of both insurance and long-term resilience building. As rainfall declines and temperatures increase, rain-fed agriculture becomes too risky.

The case study indicates that data, early warning, and response capability are available to some degree, but they are weakly connected. While poor, marginalised, and conflict-affected populations lack adequate support or resources, a meaningful target would be to use regional data and research skills to improve warning systems and readiness for timely responses. This process should also aim to involve all forms of knowledge, including satellite observations interpretated for the Horn's context, together with pastoralist reports on the health of their animals. These targets would contribute to avoiding drought and famine disasters.

20 United Nations Convention to Combat Desertification (UNCCD), "*Impact of the Great Green Wall Initiative*"

Step 2: Future Trends

People

- Rapid population growth means that the EAC population is expected to pass 400 million people by 2040.
- Internal migration, especially from rural to urban areas, continues to rise.
- Chronic food insecurity, currently affecting 10 percent of the population is projected to worsen, potentially affecting over 40 million people within the next 20 years.
- Youth unemployment rates have remained very high across the continent. In 2022, approximately 12.7 percent of African youth were unemployed, a figure mirrored in the East and Horn of Africa region, according to the International Labour Organization. Government officials report that each year an average 800,000 young people enter the workforce in search of employment. However, economies in the region are struggling to create enough jobs. Conflict, political instability, drought, and other factors contribute to limit labour and work opportunities. In addition, young women often face gender discrimination, where employers show a striking bias towards hiring young men over young women.[21]
- Tens of millions of Africans are expected to migrate in response to water stress, reduced crop productivity and sea level rise associated with climate change.121 In East Africa, the number of climate-related internal migrants (moving within countries) is projected to reach more than 10 million by 2050 for a 2.5°C global warming scenario.[22]

Planet

- Drought: Since 2005, the frequence of droughts has doubled, occurring once every three years instead of once every six years. Droughts have also become more severe in the long and summer rainfall seasons than in the short rainfall season. Several prolonged droughts have occurred, predominantly in arid and semi-arid regions over the past three decades.
- Extreme rainfall and flooding: East Africa has experienced significant rainfall variability and intense wet spells. Widespread flooding events have affected most countries, including Ethiopia, Somalia, Kenya and Tanzania.
- Water Disruptions: Disruptions in water availability, such as during droughts or infrastructure breakdown, jeopardise access to safe water and adequate sanitation, undermine hygiene practices and contaminate the environment with toxins.70 Cholera outbreaks are anticipated to severely impact East Africa during and particularly after El Niño-Southern Oscillation events.
- Future Warming: Warming temperatures are expected to negatively affect food systems in Africa by shortening growing seasons and increasing water stress.[23]

Prosperity

- Since 90 percent of the region's farmers depend on rainfed agriculture, any disruption in rainfall rates will have severe consequences for food production and livelihoods.[24]
- While global inflation is expected to decrease 4.4 percent by 2025, high inflation rates in services and transportation at 5 percent, combined with heavy reliance on grain imports, expose these nations to global price spikes and supply chain disruptions.[25] This may impact food affordability and availability.
- Youth unemployment, which is currently high, is expected to increase further, exacerbating socio-economic challenges.
- African governments face growing debt problems. Some economies have had to allocate 70 percent of the national budget for debt repayments.

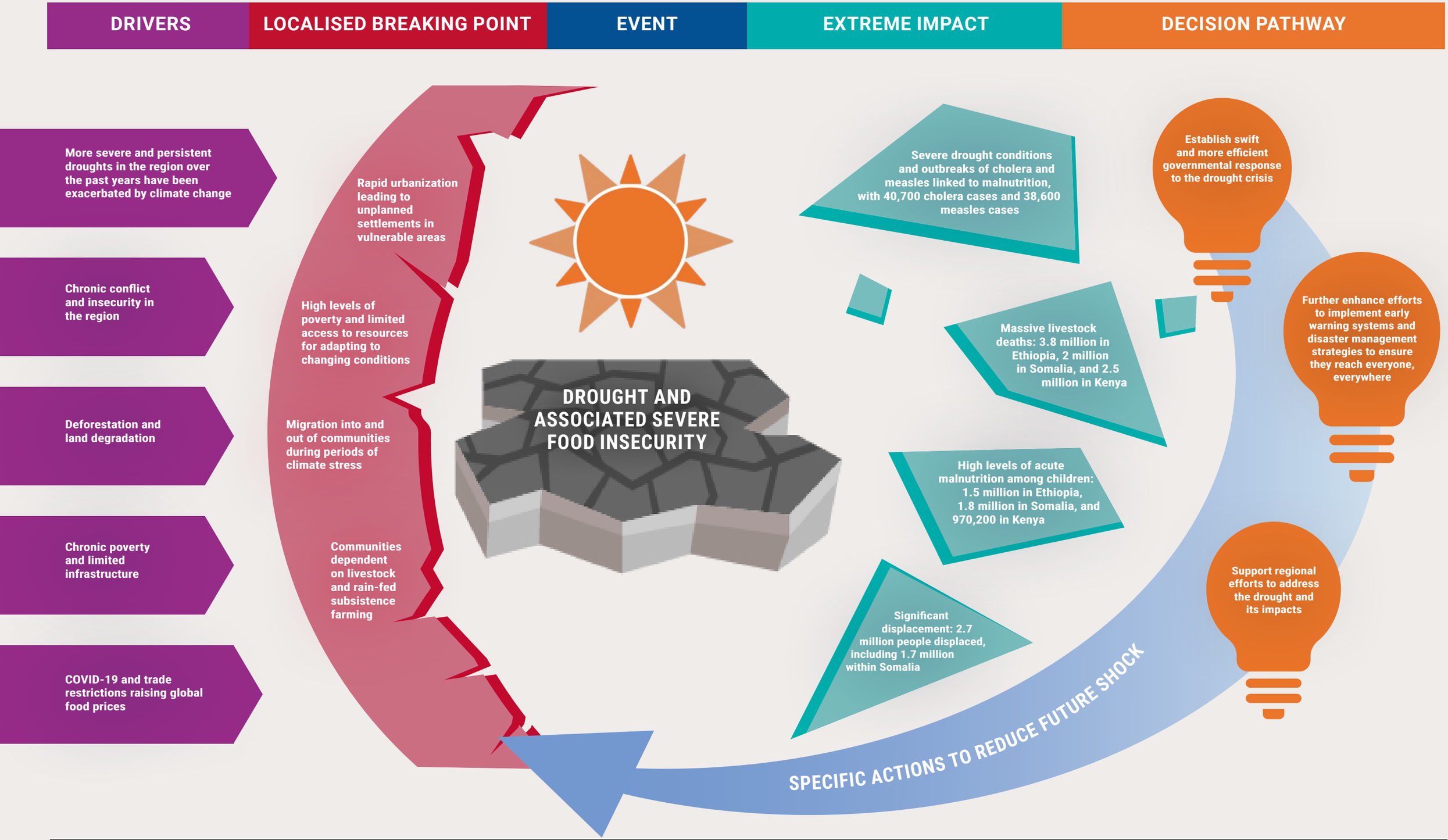
21 IOM Ethiopia, 2022
22 CDKN et al., 2022
23 Ibid.
24 Ahmed, 2021
25 IMF, 2024 (b)

STEP 3: Forensic learning

This section aims to encourage dialogue around the forensic analysis to foster improved decision making. The areas for consideration below are envisaged as an input to stimulate in-country discussion and action plan on future disaster prevention and enhanced disaster risk management

	People	Planet	Prosperity
Learning from the past	Drought and flood related humanitarian need is most acute among rural pastoral communities who lack access to social safety nets. In some areas, drought has contributed to conflict and displacement. It destroys livelihoods and creates new stress on host communities.	Rapid urbanization has led to unplanned settlements in floodplains and high-risk areas. Deforestation and land degradation have reduced the environment's capacity to absorb extreme climate events. Water intense agricultural and land management practices, such as deforestation and draining of swamp areas, are driving drought and desertification, and are not sufficiently regulated.	Poor infrastructure and transportation services hinders economic development in high-risk areas. Economic reliance on subsistence agriculture leads to economic hardship and food insecurity. The most vulnerable people are dependent on water for their livelihoods and have little access to economic or social safety nets.
Resilient features	Some countries have established early warning systems, and these continue to improve. Pastoral populations are experienced in adapting to diverse weather events. Coping strategies include migration and food source diversification.	In some areas, regreening initiatives and the promotion of sustainable land management practices have effectively reduced land degradation rates.	
To inform the future	Involve local communities in decision-making and disaster risk solutions. Strengthen social safety nets such as food assistance and cash transfer programs	Shift towards climate-smart agriculture, reducing water use and building resilience to extreme conditions. Promote practices like drip irrigation and rainwater harvesting to improve water efficiency. Reforestation and sustainable land use investment can help to reverse desertification trends. Diversify agriculture towards more drought resistant crops.	Diversify pastoral economies into rural tourism and manufacturing. Strengthen transnational coordination between governments. Invest in transportation networks and logistics. Invest in local markets for livestock, as well as processing and storage facilities, to reduce reliance on imported food.

Horn of Africa Floods and Drought / 2020-2023



US wildfire / 2021

Case Studies No 3

Sly Park, California USA - August 24, 2021: The Caldor Fire sends smoke into the air over the tree covered mountains at Jenkinson Lake

Source: Shutterstock

Step 1 – Understanding the disaster DNA

What Happened?

In December 2021, Boulder County experienced the most destructive wildfire in Colorado's history. The fire began in a grassy area in the suburban town of Marshall and spread rapidly due to strong winds, which reached up to 160 kilometres per hour (45 meters per second). An unusually wet spring had led to abundant grass growth, which, combined with an exceptionally warm and dry summer and fall, followed by a lack of snow, created ideal conditions for the fire to spread quickly.

Despite early and accurate warnings, the fire spread rapidly and unexpectedly. It caused an estimated $500 million in damages.[26] Severe wildfires like this one also have impacts which stretch into the long-term, including erosion, mudslides, road closures, degraded water quality and lives that need to be rebuilt.

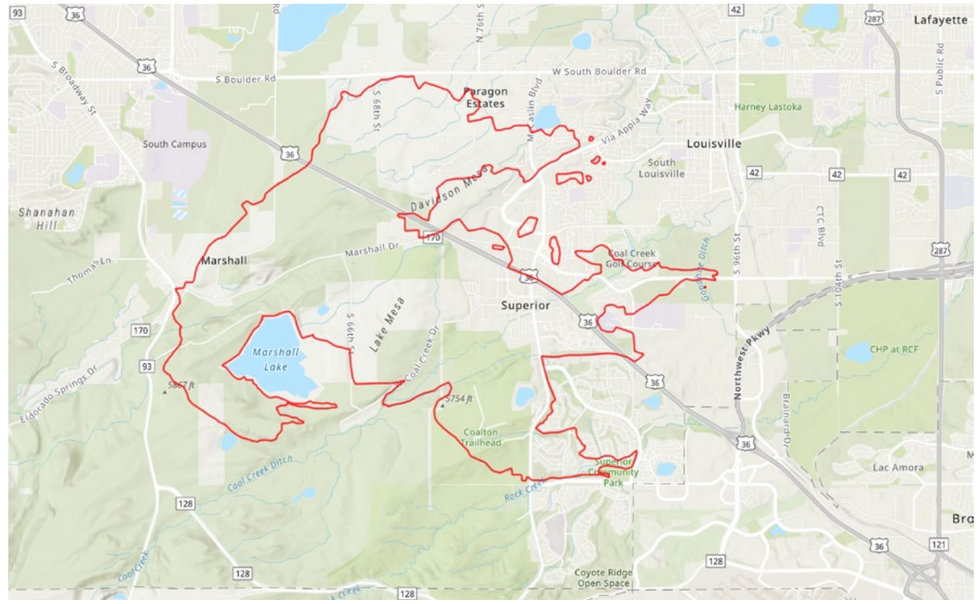
Exposure: Where was damage concentrated?

More than 1,000 homes were destroyed in the towns of Superior and Louisville, as well as in unincorporated areas of Boulder County. The level of destruction in these suburban communities was unprecedented. Within less than 24 hours, the fire had burned over 2,500 hectares (about 6,200 acres) of land.

The fire released toxic polycyclic aromatic hydrocarbons into the air, posing long-term health risks. Elevated levels of these carcinogens were found in the dust within homes, raising concerns about respiratory and other health issues.[27]

Natural hazards, including high wind and drought, played a vital role. These hazards, combined with unusual weather, abundant vegetative growth, the area's natural topography, and characteristics of the built environment - such as dense suburban housing and interwoven green spaces - propelled the fire.[28]

Figure 7. In one day, the fire burned 2,500 hectares of land in Boulder County

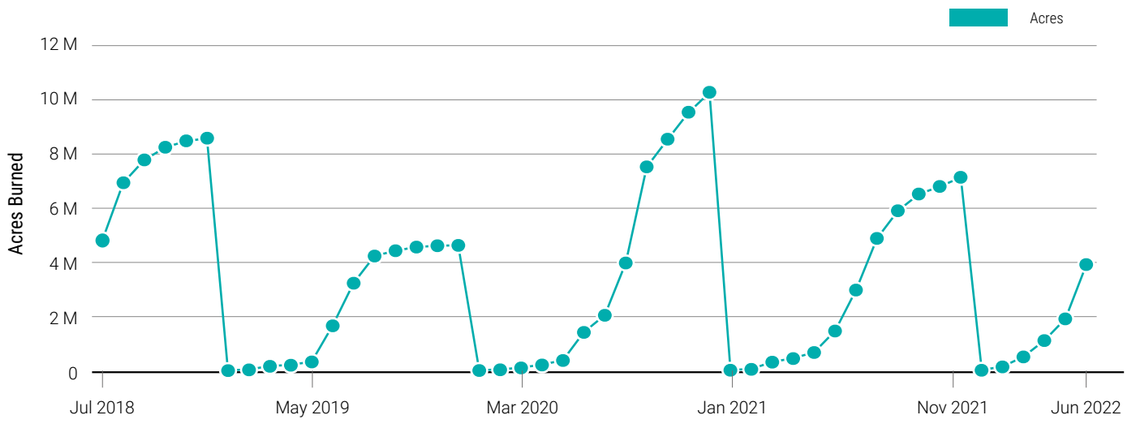


Source: US Census Bureau. Open Innovation Lab. 2023.

The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

26 The Denver Post, 2022
27 Silberstein, 2023
28 Federal Emergency Management Agency (FEMA), 2023 (b)

Figure 8. **Although the number of fires was similar to those recorded in previous and subsequent years, the damage caused by the fires in Marshall, in terms of hectares burned, was significantly more severe than before and after**



Source: National Centers for Environmental Information and the National Interagency Fire Center (n.d.). U.S. Wildfires.

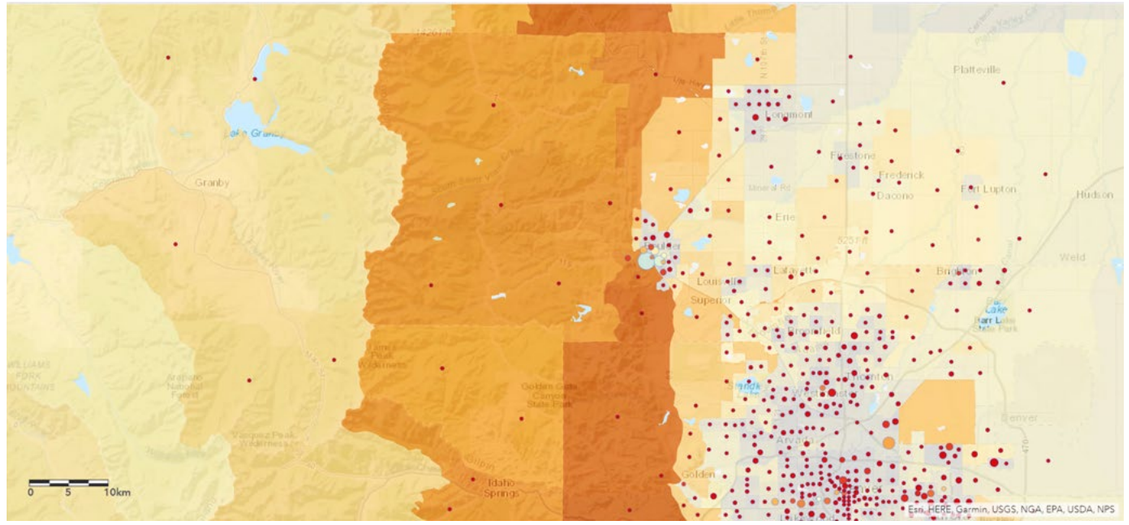
Table 2. **The direct costs of the Marshall fires were significantly higher than any previously recorded, being almost six times greater than the second most costly.**

Rank	State	Month	Type of facility	Estimated loss
1	Colorado	December	Wildand / urban interface, Marchall Fire	$ 678
2	Illinols	June	Chemical manufacturing	160.0
3	California	November	Textile manufacturing	128.0
4	Wisconsin	February	Ship in for repairs	100.0
5	Tennessee	July	Cereal manufacturing	98.6
6	Nevada	January	Apartments under construction	35.0
7	Tennessee	March	Rubber manufacturing	35.0
8	Colorado	October	Apartment building (81 units)	30.2
9	Texas	February	Werehouse with foam products	26.0
10	California	January	Restaurant	25.2

Note: Loss data shown here may differ from figures shown elsewhere for the same event due to differences in the date of publication, the geographical area covered and other criteria used by organizations collecting the data

Source: National Centers for Environmental Information and the National Interagency Fire Center (n.d.). U.S. Wildfires. (NCEI).

Figure 9. **Many of the forest fires recorded between 1984 and 2022 occurred in areas with households where monetary poverty levels are above the national average**



Source: UNDRR using data from Monitoring Trends in Burning Severity Agency and Census USA, June 2024.

The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Flames light up the night sky for miles around as the CalWood fire rages through the mountains in Boulder County, Colorado, October 17, 2020

Source: Shutterstock

Vulnerability: Who was affected and why?

The severity and behaviour of the Marshall Fire were influenced by several factors. Many affected areas had design features that inadvertently increased wildfire vulnerabilities. Elements such as drainage ditches for flood control and greenbelts for recreation acted as wildfire "superhighways" due to unmanaged biomass and hazardous vegetation. These open spaces and extensive grasslands allowed the fire to penetrate deeper into built environments. While valuable for flood control and recreation, they exacerbated the fire's spread by channelling winds and increasing fire intensity. In addition, highly flammable materials, such as wooden roofs and dense vegetation close to homes, contributed to the extensive damage.[29]

The use of flammable building materials and the lack of fire-resistant building codes for existing structures further increased vulnerability and the extent of the damage. Key factors affecting a home's wildfire risk included construction materials, proximity to fire hydrants or stations, elevation, emergency vehicle access, nearby vegetation, and weather patterns. Several manufactured home communities in Boulder County were heavily damaged or destroyed by high winds during the Marshall Fire.[30]

Power interruptions restricted the response by limiting water availability from hydrants, ponds, lakes, and stormwater facilities. Low water pressure in community hydrants also hampered firefighting efforts. High winds made air suppression unusable, as firefighters reported that the winds either blew the water from hoses back at them or dispersed it into a fine mist.[31]

Table 3. The direct costs of the Marshall fires were significantly higher than any previously recorded, being almost six times greater than the second most costly.

Demographic Measure	Boulder Country	States of Colorado	National Average
Population, 2020	330.758	5.773.714	N/A
Population Increase 2010 to 2020	12.3%	14.8%	7.4%
Median Household Income	$ 88,535	$ 80,184	$ 71,400
Poverty Rate	11.7 %	9.7 %	11.4 %
Homeownership Rate	61.6 %	65.2 %	64.6 %
Housing Units Constructed after 1990	40.7 %	N/A	N/A
Media Home Value	$ 575,500	$ 397,500	$ 244,900
SVI Calculated Value (CDC) *	0.2062	N/A	N/A

Source: National Centers for Environmental Information and the National Interagency Fire Center (n.d.). U.S. Wildfires. (NCEI).

29 Ibid.
30 Ibid.
31 Ibid., page 26

Evacuation was complicated by several challenges, including compromised power, gas and water lines, congested roads, and sub-zero temperatures. Lower-income and vulnerable populations faced additional challenges. These groups, including older adults, persons with disabilities, and those without reliable transportation, often had limited access to emergency services and support networks.

Insufficient insurance coverage added to the pain. The fire's rapid spread caused many people to lose everything they owned. Residents discovered that their insurance did not cover the full cost of rebuilding, leading to financial strain and prolonged recovery. This vulnerability was particularly severe for those already struggling before the fire. The destruction of commercial properties and job losses also created economic hardships, especially for those without financial safety nets.

Resilience: what factors limited the impacts?

Nationally, building codes and regulations existed to mitigate fire risk, including requirements for fire-resistant construction materials and defensible space around buildings. However, enforcement and specificity varied across regions, as the Marshall Fire showed.

The Colorado State Forest Service's Wildfire Risk Map delineated wildfire risk, including burn probability maps and reference layers such as large fire perimeters, community wildfire protection plan boundaries, Firewise USA sites, and a social vulnerability index. Tools available included a wildfire risk reduction planner and a wildfire risk viewer.[32]

At the time of the Marshall Fire, Colorado lacked a wildland-urban interface code covering the transition zone between unoccupied land and human development.[33] Wildfire-specific standards were insufficient.[34] The state's enhanced hazard mitigation plan (E-SHMP), updated and approved in 2023, now includes eight goals:

1. Minimize the loss of life and personal injuries from natural hazard events.
2. Reduce losses and damages to state, tribal, and local governments, as well as private assets.
3. Reduce federal, state, tribal, local, and private costs of disaster response and recovery.
4. Support mitigation initiatives and policies that promote disaster resiliency, nature-based solutions, cultural resources, historic preservation, and climate adaptation strategies.
5. Minimize interruptions to essential services and activities.
6. Incorporate equity considerations into all mitigation strategies.
7. Improve coordination of risk mitigation among public, private, and non-profit sectors.
8. Create awareness and demand for mitigation as standard practice.

Boulder County's 2020 Comprehensive Plan addressed wildfire threats, emphasizing codes, standards, public education, and land use management. It aimed to improve the wildfire resiliency of existing housing stock through voluntary incentives, such as low-interest loans for replacing wood roofs with Class A fire-rated roofs. However, this goal was yet incorporated into local ordinance and remained a voluntary approach.

Local municipalities had community wildfire protection plans, zoning regulations, and programs promoting fire-resistant landscaping and building materials. The effectiveness of these programs depended on local implementation and enforcement. Some plans incentivised homeowners to invest in resilience including through lower-cost insurance premiums (See box: "Deep Dive: Insurance coverage and the Colorado Fire").

Partnerships between local governments, fire departments, and community organizations, such as Restoring Our Community, played a crucial role in promoting wildfire resilience and supporting survivors in housing recovery.

Rather than relying on voluntary measures, the application of good governance measures - such as enforceable wildfire codes and state regulations - would decrease wildfire risk and increase the capacity of insurance companies to provide coverage, an example of making the "right investment". Likewise, through "meaningful inclusion" and "good governance", the Wildfire Partners Program has improved the insurability of homeowners. This, combined with grants for home improvements and additional grants through the May 2023 Colorado legislation are also examples of the "right investment". All these elements could help prevent future disasters.

32 Ibid., page 34
33 Ibid., page 32
34 Ibid., page 55

Step 2: Future Trends

People

- More than half of all Coloradans live in the wildland-urban interface (WUI), placing them at higher risk of wildfires.35
- Continued urbanization of these areas increases the potential for future wildfires. Some states have witnessed more than 50 percent population growth in WUI areas between 1990 and 2020. This trend shows few signs of slowing in the future.36
- Wildfire smoke in Colorado has been associated with increased hospitalizations for asthma, chronic obstructive pulmonary disease and some cardiovascular health outcomes.[37]

Planet

- Since 2000, there have been 60 wildfires larger than 10,000 acres in Colorado, including six fires larger than 100,000 acres. All but one of these larger fires occurred after 2017. The annual area burned by wildfires in the forested areas of Colorado and adjacent areas of New Mexico and Wyoming increased by over 300 percent from the 1984-2000 period to the 2001-2017 period. The average elevation at which these wildfires occurred shifted upwards by over 1000 feet between 1984 and 2017, consistent with how warming is moving temperature regimes upslope. Wildfire risk in Colorado is expected to worsen significantly by the mid-21st century compared to the late 20th century, as additional warming further increases fuel dryness and enhances fire ignition and spread.38
- On average 2.8 million acres of forest burn annually in the US.39
- When unhealthy forests are in proximity to populated areas, with materials that act as high fuel loads, they can create destructive wildfires that spread to urban areas.

Prosperity

- Property loss due to wildfires increased by over 140 percent between 2013 and 2022, and this trend is not slowing.[40]
- Homeowners face considerable financial burdens due to property damage, while communities incur high expenses related to firefighting and post-fire rehabilitation. Colorado is likely to be the next state to face extremely tight, or non-existent, homeowner insurance policies due to increasing wildfire threats. The average homeowner insurance premium in the state increased 51.7 percent between January 2019 and October 2022. Meanwhile, some new homeowners in the state are struggling to obtain insurance policies.[41]
- CoreLogic, a firm that provides risk estimates to insurers, utilities and local governments, estimates that 332,716 homes in Colorado are at moderate, high or very high risk of damage from wildfires. Rebuilding those homes, if they were destroyed, would cost an estimated $140.9 billion. Colorado has the second highest wildfire exposure to its housing stock in the nation.[42]

35 Colorado State Forest Service, 2023
36 United States Department of Agriculture (USDA), 2023.
37 Colorado State University, 2021
38 Bolinger, 2024
39 Hawbaker, 2012
40 US Fire Administration, “Nonresidential fire estimate summaries (2013-2022)”
41 Bassler, 2024
42 Svaldi, 2023

Step 3: Forensic learning

This section aims to encourage dialogue around the forensic analysis to foster improved decision making. The areas for consideration below are envisaged as an input to stimulate in-country discussion and action plan on future disaster prevention and enhanced disaster risk management.

	People	Planet	Prosperity
Learning from the past	There are many national and local guidelines and codes for fire protection, but, in areas such as building and landscaping, most are voluntary, or enforcement is limited. Evacuation and recovery were more challenging for vulnerable populations, including older adults and those without reliable transportation. The critical role of immediate mental health support in disaster recovery is underscored by Boulder County’s swift response to the wildfire crisis, including the mobilization of 250 therapists and free counselling to over 500 affected individuals.[43] The fire caused air quality to decline. Fire damage may have increased the toxins in home and increase health problems.	Anthropogenic climate change has intensified wildfire risk in Colorado, contributing to increased burned area, longer fire seasons, and more severe fires through rising temperatures, decreased precipitation, and altered atmospheric circulation.[44] As the climate shifts, hazard patterns are also changing, increasing the risk of grassland fires in Colorado Unmanaged open spaces and greenbelts inadvertently facilitated the fire’s spread, highlighting challenges in land use planning and management. Over the last 35 years, the number of reported wildfires has stayed approximately the same. However, in terms of acreage, the scale of disasters has grown. Different authorities are protecting wildlife inconsistently. Only those in charge (municipalities) are implementing fire risk reduction measures..	Risks are growing, whether measured in lives lost or property damaged. Post-fire impacts include landslides, flash floods, and mudslides risk. Financial vulnerabilities were exacerbated for lower-income households, who tended to have less insurance coverage and struggled with the costs of rebuilding. While businesses and homes were insured, coverage of homes was often insufficient and did not cover replacement costs. Delays in payments significantly hindered recovery.
Resilient features	The community’s rapid evacuation response and mutual aid efforts during the **fire de**monstrated strong social cohesion and support networks. Inclusive emergency preparedness plans ensured vulnerable populations could evacuate safely and have access to support services. Community partnerships provided effective in coordinating emergency response efforts and providing essential services during and after the disaster.	Efforts by local communities and organizations to implement wildfire resiliency programs, such as the Wildfire Partners Program, demonstrated a commitment to sustainable land management and fire prevention. The adoption of wildfire risk reduction strategies and policies by local governments and communities aimed to protect natural ecosystems and reduce the risk of future wildfires.	A state grant program was set up to fund fire-resistant improvements to homes. This supports economic recovery and resilience in the face of future wildfires. The creation of a Wildfire Resiliency Code Board aims to adopt statewide building standards that promote structural hardening and reduce fire risk.

43 Ruder, 2022
44 Hicke et al., 2022

To inform the future	Provide targeted financial support and temporary housing / rebuilding assistance for low-income and underinsured residents in order to address disparities in recovery. Increase availability of health and mental health services, including counselling and therapy, specifically tailored to trauma recovery from wildfires. Work with health and toxicology departments to monitor and assess toxin levels and potential health risks from fire-related exposure.	Strengthen regulations on land use and management, such as maintaining greenbelts and drainage ditches. This will reduce the risk that these areas act as wildfire superhighways. Incorporate multi-hazard risk mitigation features into urban planning and infrastructure design. Invest more in detection and firefighting services to improve fire containment capabilities. Monitor wildlife recovery and research wildfire impacts. Develop comprehensive wildfire safety codes and standards at both state and local levels.	Improve understanding of insurance coverage and the importance of maintaining adequate policies. Fast-track permits and inspections for rebuilding homes and businesses. Provide grants or low-interest loans for rebuilding efforts with fire-resistant materials. Offer financial assistance and resources to help local businesses recover and reopen. Implement tax relief measures for affected businesses and homeowners.

Aerial view of the aftermath from Marshall fire. Drone photo shows neighborhood with an untouched house surrounded by ashes and burned down houses, January 17, 2022

Source: Shutterstock

Deep Dive: Insurance coverage and the Colorado Fire

Colorado's high wildfire risk and frequent hail claims make it difficult for some homeowners and businesses to find insurance, leading some providers to withdraw from high-risk areas.[45] Brokers and agents use scoring tools to determine potential fire damage and set insurance premiums accordingly.

In the wake of the 2023 wildfires, many homeowners struggled with insurance claims. Surveys found that only 4 percent of respondents expected their insurance to cover all rebuilding costs, while about 10 percent expected insurance to cover less than half of their expenses. Lower-income households faced greater underinsurance challenges. Nearly half of households with incomes above $150,000 expected insurance to cover at least 75 percent of their costs. This compares with just a quarter of households with incomes less than $75,000, who expected the same.[46]

The state estimated the total rebuilding cost using three calculations. At $250 per square foot, underinsurance was worth an estimated $39 million. At $300 per square foot, underinsurance was worth roughly $100 million. At $350 per square foot, estimates were as high as $179 million. In total, over $1 billion in insurance claims have been filed.[47]

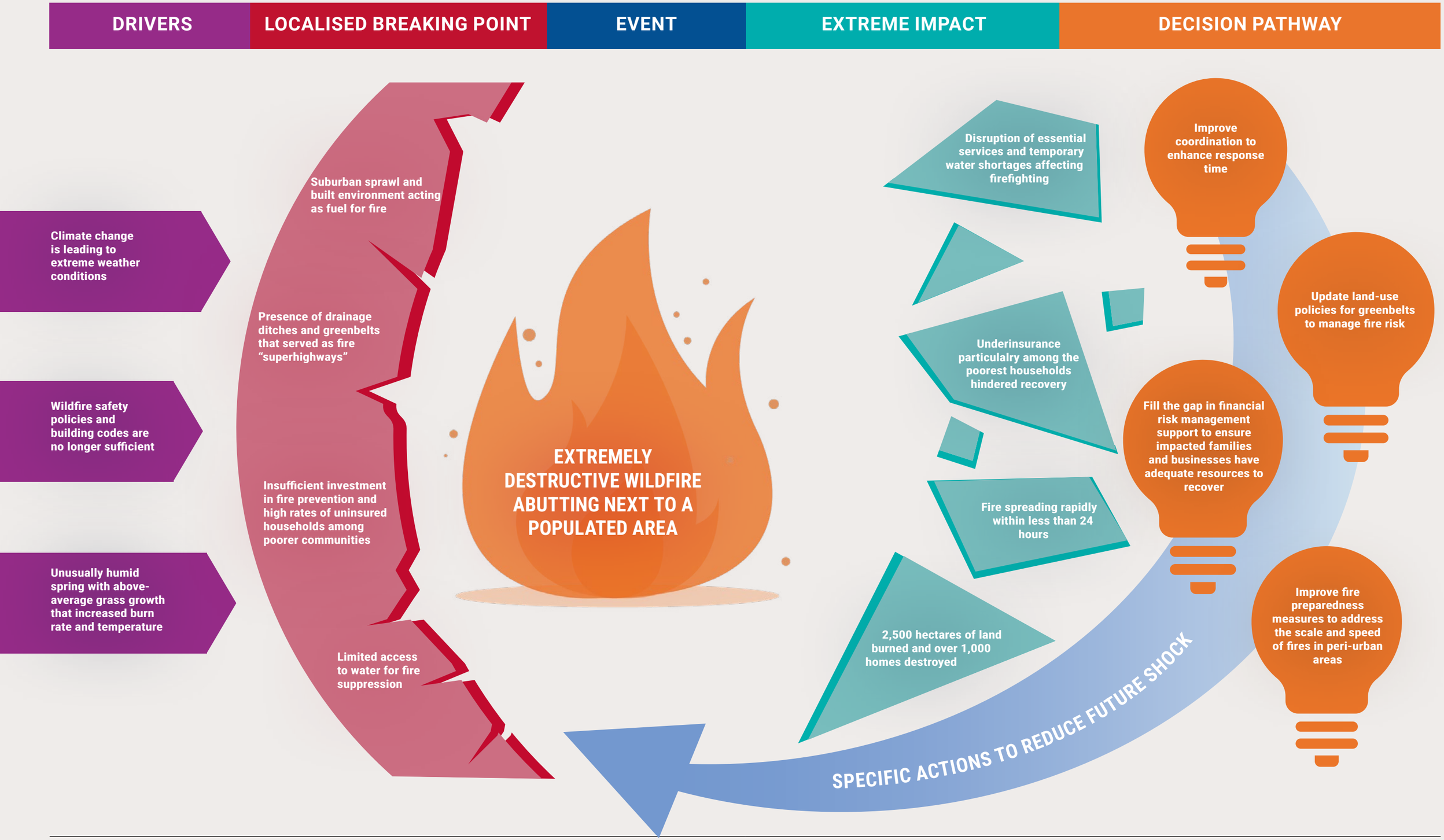
Some counties have established local community wildfire resiliency programs to support homeowners in preparing for future wildfires. For example, the Wildfire Partners Program in Boulder County offers property-level risk assessments and detailed recommendations for mitigation, as well as funding opportunities. Participants who pass final inspections receive a Wildfire Partners Certificate, which is recognized by local insurance companies.

Similarly, the RealFire Program in Eagle County, offers free property assessments by qualified local assessors. Homeowners receive a list of recommended mitigation actions to earn a RealFire certificate, which can help with potential insurance benefits.[48]

45 Cookson, 2023
46 Rumbach et al., 2023
47 Hamilton Insurance Partners, "The Marshall Fire Insurance Fiasco: What Went Wrong?"
48 Federal Emergency Management Agency (FEMA), 2023 (b)

Source: Shutterstock

US wildfire / 2021



Jamaica Floods / 2021

Case Studies No 4

Floods, Jamaica

Source: Flickr/Christina Xu (CC BY-ND 2.0)

STEP 1- Understanding the disaster DNA

What Happened?

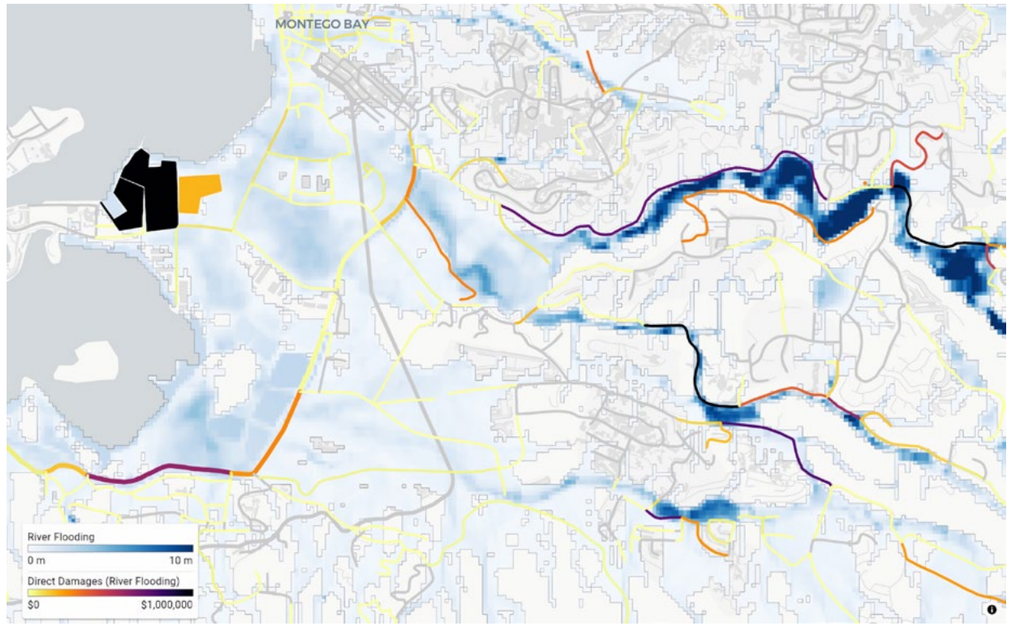
On January 8, 2021, heavy rains deluged Jamaica's Montego Bay, flooding roads and damaging vehicles and buildings alike. A total of 40mm of rain fell in a short period,[49] affecting an estimated 933 people, including several injuries in the town. Montego Bay is home to a major cruise ship port, an airport, commercial centre, beach resorts, and golf courses.

The event was not unique in the sense that Montego Bay has experienced several major floods in the past decade, occurring roughly once every two years.

In November 2017, for example, 94mm fell within 4 hours, inundating the town centre, flooding businesses and sweeping cars away. At that time, floodwaters reached about 1.5 metres, affecting some 392 people and impacting critical infrastructure such as gas stations and Sangster International Airport.[50]

49 UNDRR, 2023
50 Ibid.

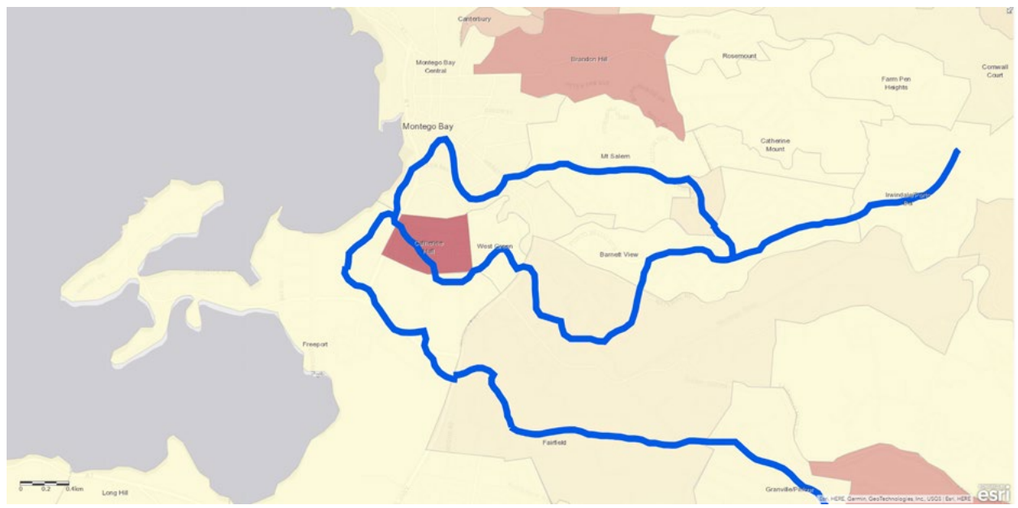
Figure 10. **Heavy rain in April 2022 caused severe flooding in St. James and Hanover parishes in Jamaica. The Montego River watershed, spanning approximately 11,657 hectares, was significantly impacted**



Source: Oxford Programme for Sustainable Infrastructure Systems (OPSIS) and the Planning Institute of Jamaica

The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Figure 11. **Areas characterized by high rates of food poverty are disproportionately affected by flooding**



Source: UNDRR

The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Exposure: Where was damage concentrated?

These two floods in Montego Bay both affected business owners and residents. Floodwaters blocked main access routes to Sangster International Airport and major roads, with most damage occurring in low-lying areas.

Informal settlements were hit particularly hard, as debris-filled floodwaters clogged drains and flooded businesses such as banks, gas stations, supermarkets, shopping centres, and auto shops. Poorly constructed structures and household items were heavily damaged. These settlements, characterized by higher population densities and multiple houses in one yard, faced greater challenges in recovering and replacing damaged items.

Formal residences, mainly located on the town's outskirts, also experienced flooding. These households were marooned, and their properties and household items were damaged. Although structural damage was minor, the losses were significant.

Businesses, primarily located in the town centre, lost revenue but generally recovered more quickly. However, the loss of business directly impacted households who relied on those businesses as their primary income source. This was also true for the residents of informal settlements.

As Montego Bay continues to expand, including on marginal lands, flood risk remains a priority issue. Irregular settlements reflect social inequality, and authorities have not yet prohibited urbanization in high-risk areas or provided housing alternatives for those in informal settlements. Promoting affordable housing with safe, healthy spaces and easy access to work is essential to mitigating flood risks.

Flooded residential area, Jamaica

Source: Flickr/Christina Xu (CC BY-ND 2.0)

Vulnerability: Who was affected and why?

Tourism, Montego Bay's most important economic sector, was significantly affected. The 2017 and 2021 floods disrupted tourism by flooding hotels and blocking key roads. Many people from the informal settlements work in hotels, and the floods prevented them from going to work for several days or even weeks. The drainage problems also impacted tourism.

The floods mainly affected the poorer population, highlighting both the causes and symptoms of urban sprawl. Population growth and density increased pressure on the drainage infrastructure, especially near settlements on public lands close to parks and open spaces. When the rains came, garbage accumulated in public spaces, rivers and drains, contributing significantly to the flooding.

Limited research has been completed on the public health issues related to water and sanitation following the 2017 and 2021 floods.

Resilience: what factors limited the impacts?[51]

Flooding events in Montego Bay are being carefully assessed to understand their impacts, and to develop strategies for better resilience against future floods. Challenges such as limited official resources for enforcing building codes and managing the many facets of unplanned urban sprawl, including maintaining debris-free drainage systems, underscore the need for meaningful inclusion of a variety of stakeholders.

Engaging local communities and businesses in meaningful ways is vital for effective governance. When governments and authorities properly connect with these groups to discuss the impacts of their actions and reach a shared agreement on the mindset and participatory actions required, then positive results can be achieved, sometimes surprisingly quickly. Meaningful inclusion is a vital part of avoiding disasters.

Despite the challenges of urban sprawl, Montego Bay is working to reduce its disaster risk through workshops, simulations, and community meetings. These activities build capacity and awareness, while bolstering preparedness and response capabilities at both political and operational levels. Hazard information is shared online and through products such as posters to educate residents about flood risks and other hazards.

Updating and enforcing the national building code and land use regulations are seen as vital. The proliferation of informal settlements along major drainage networks exacerbates flooding, as these settlements often obstruct the flow with accumulated waste. Aging drainage infrastructure further compounds the issue, particularly as urban expansion introduces new tributaries without corresponding upgrades.[52]

Local authorities clean the main drains to mitigate flood risks, but improper waste disposal in informal settlements hinders these maintenance efforts. Debris accumulates on beaches and in ports, detrimentally impacting coastal ecosystems.

Public consultations, research studies, and assessments involve diverse stakeholders such as NGOs and vulnerable community residents. Regulatory frameworks mandate environmental impact assessments for proposed developments in sensitive coastal areas. Hazard information is incorporated into land use planning and environmental protection strategies. A squatter management unit collects and analyses data on informal settlements.

Enforcement remains an issue on marginal lands throughout Montego Bay, but the accelerating expansion of informal settlements is driven by the demand for work and increased access to amenities.[53] While the housing needs of informal settlers are evident, there is not enough land available to build housing with easy access to employment and services in the town. Most land on the outskirts of town is privately owned, with some housing developments for middle and high-income earners.

Restrictive measures should be put in place for construction in areas where the flood threat is identified as high or very high. Developing policies, regulations, codes and other instruments that support stronger governance around territorial planning is a key element in reducing flood risk.

To the extent possible, enforcement of laws to control littering and improper dumping can be improved, with an emphasis, for example, on fines for violations. Effective solid waste disposal strategies can also be promoted in communities through education and public awareness. Periodic cleaning of creeks and ravines should continue, and drainage networks in and around the city should be improved.

51 Mckenzie et al. 2022
52 UNDRR, 2023
53 Ibid.

STEP 2- Future trends

This section looks at key root causes or emerging issues identified above and provides a snapshot of potential 'business and usual' trends where action now could prevent or reduce disasters in the future.

People

- Jamaica is the 35th most densely populated country in the world, with 2.9 million people living in an area of 10,991 square kilometres. Montego Bay, a key town, has a population of 110,000.[54] The percentage of Jamaica's population living in urban areas is set to rise from 56.3 percent in 2020 to 62.8 percent in 2035. In 2011, just 14.5 percent of the population was connected to sewerage. Some 46.4 percent of the population live within walking distance to public transport.[55]

- Jamaica ranks among the top three most exposed countries in the world to multiple natural hazards. It has the second highest economic risk exposure to two or more hazards, with 96.3 percent of its GDP at risk. The areas most exposed to and least equipped to deal with hazards such as floods and hurricanes are along the coast, where most of Jamaica's capital towns are located. Unplanned settlements in environmentally sensitive lands, such as flood plains and unstable slopes, increase the risk of natural hazards becoming disasters and the levels of damage possible.56

Planet

- Without shoreline defences, under a worst-case warming scenario by the end of the century, 5 percent or more of Kingston, Jamaica is projected to fall permanently below sea level.[57]

- The estimated per capita waste generation is currently an estimated 1.2 kg/day per person, and this is expected to increase to 1.5 kg/day due to factors such as population growth and changing consumption patterns.[58] Pollution is widespread and illegal dumping is commonplace in some communities. Large volumes of waste are dumped in gullies and rivers, which lead to flooding and pollutants in marine environments. Air pollution is affected by emissions from the transportation sector and well as from burning of waste.[59]

- In 2018, Jamaica launched its Beating Plastic Pollution Campaign, part of a global initiative, to address the challenge of plastic bags, plastic bottles, microbeads, styrofoam, and more, which fill Jamaica's streets, gullies, and harbour.[60]

- Coastal ecosystems face escalating degradation due to projected urban expansion which could intensify flood risks.

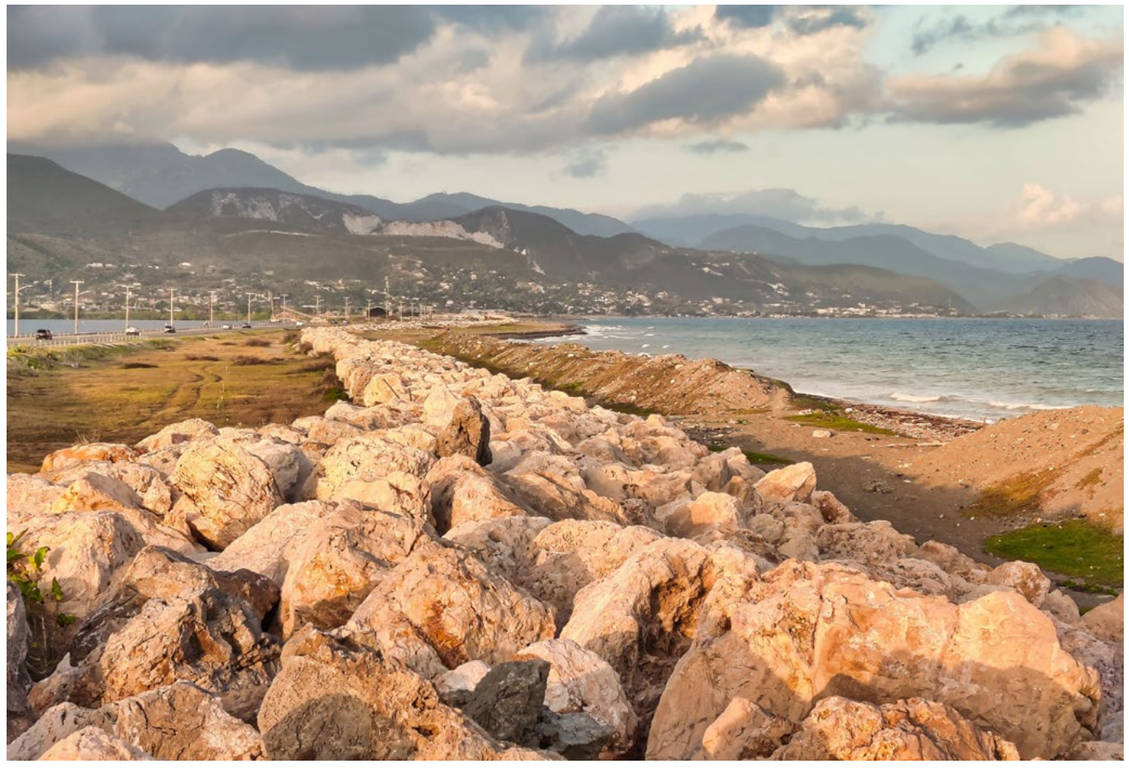
54 World Population Review, "Jamaica Population 2024 (live)"
55 UN Habitat, 2022
56 UN Environment Programme (UNEP), "Sustainability and Environmental challenges"
57 UNDP, 2023
58 Government of Jamaica, 2019
59 UNEP, "Sustainability and Environmental challenges"
60 Government of Jamaica, 2024

Prosperity

- Recurrent flooding is projected to impact tourism, infrastructure, and livelihoods.

- Inaction on improving drainage infrastructure and implementing robust urban planning measures is expected to exacerbate economic vulnerabilities and hinder sustainable growth estimated at 1.6 percent if climate resilient infrastructure is implemented.[61]

Large boulders on Palisadoes a thin strip of sand that serves as a natural protection for Kingston Harbour, Jamaica



Source: Shutterstock

61 IMF, 2024(a)

Fishing boats, Jamaica

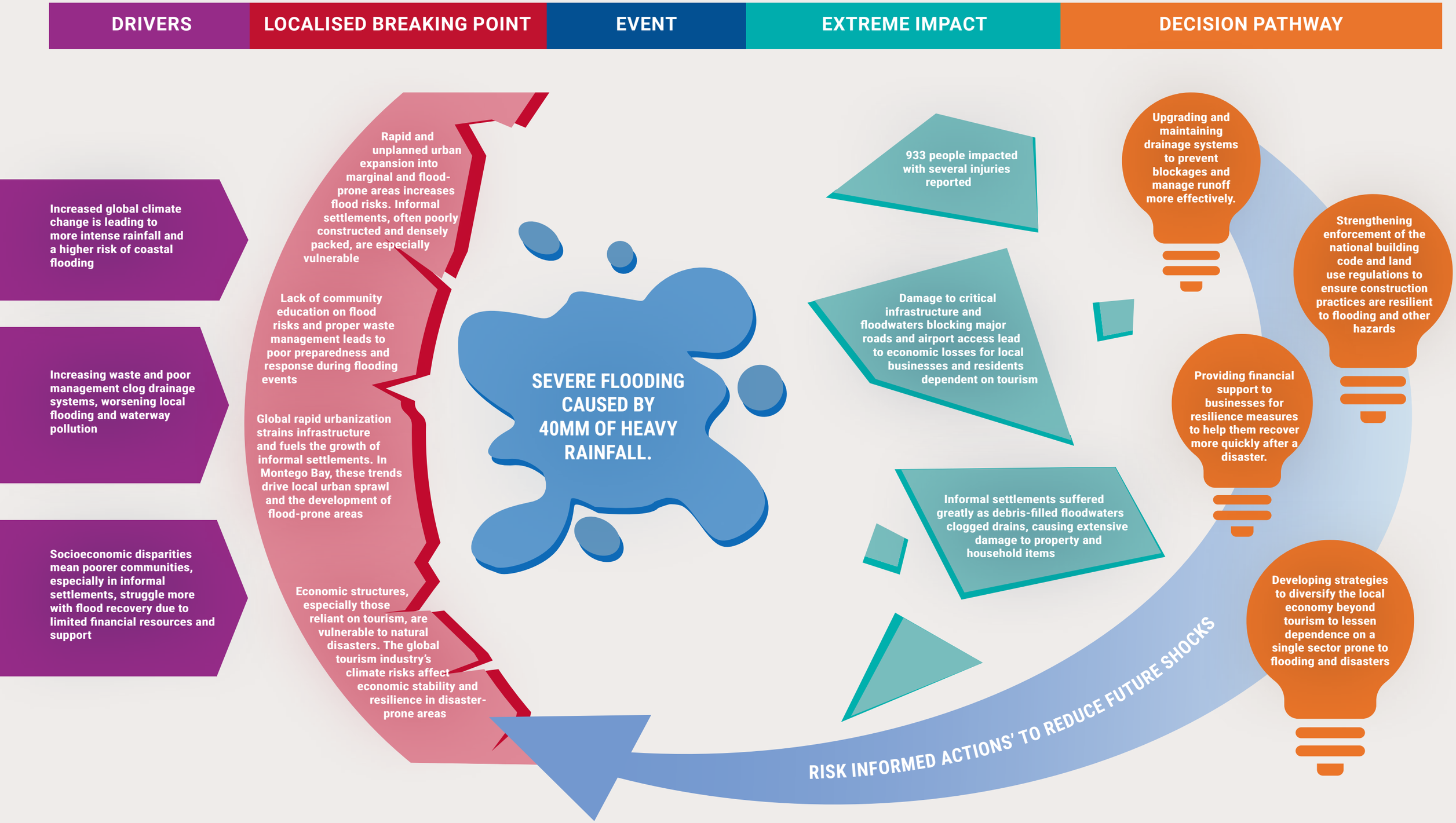
Source: Flicker, Stéphane Damour

STEP 3- Forensic learning

This section aims to encourage dialogue around the forensic analysis to foster improved decision making. The areas for consideration below are envisaged as an input to stimulate in-country discussion and action plan on future disaster prevention and enhanced disaster risk management

	People	Planet	Prosperity
Learning from the past	Recurrent floods disproportionately affect vulnerable populations, particularly those in informal settlements. These communities, which are often in low-lying areas and along drainage channels, face significant risks during extreme weather events. These events damage homes and infrastructure, posing threats to health and safety.	Improper disposal of solid waste and urban sprawl along coastal areas and drainage channels exacerbate flood risks and degrade local ecosystems. This degradation reduces the natural capacity of coastal areas to mitigate floods and support biodiversity, underscoring the need for sustainable urban planning and environmental management strategies.	Floods impact key economic sectors such as tourism and local businesses. Recurrent flood events damage critical infrastructure and disrupt business operations, leading to economic losses and hindering sustainable growth.
Resilient features	Community engagement and capacity building initiatives aim to enhance disaster preparedness and response capabilities among residents.	Local government integrates hazard information into planning and regulation. Environmental impact assessments and development regulations protect coastal ecosystems and mitigate flood risks.	National government invests in climate-resilient infrastructure and disaster preparedness to minimize economic losses, sustain tourism and support local business.
To inform the future	Enhance urban planning and regulation. Prioritize the safety of residents in informal settlements which are prone to flooding. Enforce building codes and land use regulations. Reduce vulnerabilities and protect from future floods.	Upgrade and maintain drainage to mitigate the impact of floods and safeguard coastal ecosystems. Integrate environmental assessments into urban development. Promote practices that enhance resilience.	Invest in climate-resilient infrastructure and disaster preparedness. Support partnership between government, business, and communities. Protect infrastructure, sustain tourism despite flood risks.

Jamaica Floods / 2021



Portugal heatwave / 2022

Case Studies No 6

Forest wildfire during a Portugal summer

Source: Shutterstock

STEP 1 – Understanding the disaster DNA

What happened?

During the spring and summer of 2022, Portugal experienced more than four distinct heatwaves, the most severe of which ran from July 2 to July 18. This exceptional event killed almost 2,400 people and triggered several devastating forest fires. . Mostly affected were older citizens living inland. They are often living alone and in houses not prepared for this kind of extreme heat.

The heatwave mainly impacted non-coastal inland areas of Portugal, where maximum air temperatures reached record highs at 30 meteorological stations. On July 14, the village of Pinhão in northern Portugal recorded a temperature of 47.0°C, the highest July temperature ever recorded in mainland Portugal.[62]

The heatwave also led to widespread forest fires. In July 2023, more than 50,000 hectares burned, more than double the average amount for that month over the previous decade. The fires injured dozens of people, forced the evacuation of many more, and caused damage to property, agriculture and infrastructure. One pilot died during fire suppression efforts.

Exposure: Where was damage concentrated?

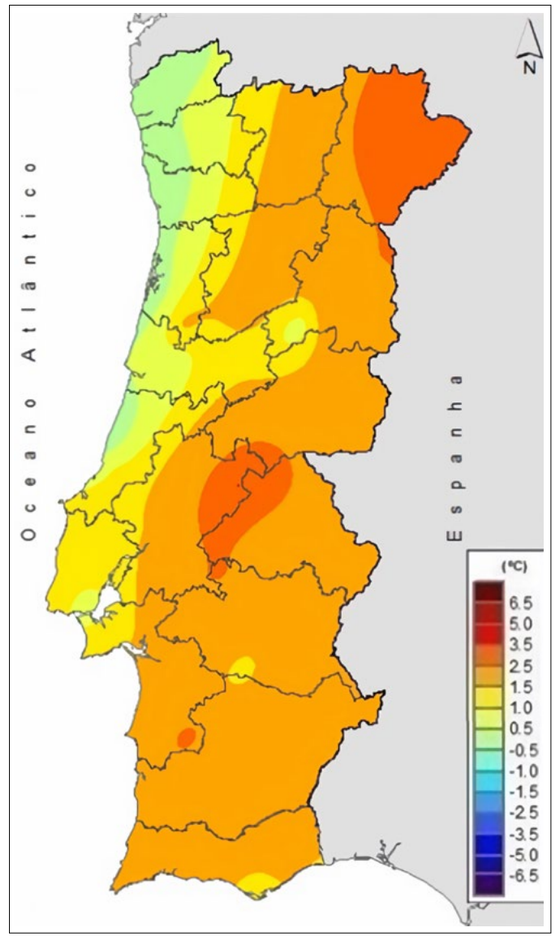
Heatwaves are common during summer on the Portuguese mainland, although the Atlantic Ocean moderates the intensity of the heat. The most affected regions are the inland areas in central and northeastern Portugal.

Wildfires are a regular occurrence in Portugal's forests, with over 18,000 fires per year and an average 107,000 hectares burned each year since 1980.[63] These fires are influenced by factors such as climate, land use changes (including afforestation and rural abandonment), and socioeconomic conditions.[64] Portugal's dense, abandoned forests are particularly susceptible to wildfires, especially in areas with sustained heat and unstable air conditions.[65]

Most homes in Portugal are not well-prepared for extreme heat. According to the 2021 Census, 83 percent of houses lack air conditioning, for example. Under current climate conditions, buildings in Lisbon have the highest Overheating Degree Hours above 26°C (ODH26) values, signifying greater risks of overheating in the summer.[66]

62 Instituto Português do Mar e da Atmosfera (IPMA), 2022
63 Global Forest Watch, 2023
64 Mateus, Paulo, and Paulo M. Fernandes, 2014
65 Elbein, 2019
66 Fürtön, 2022

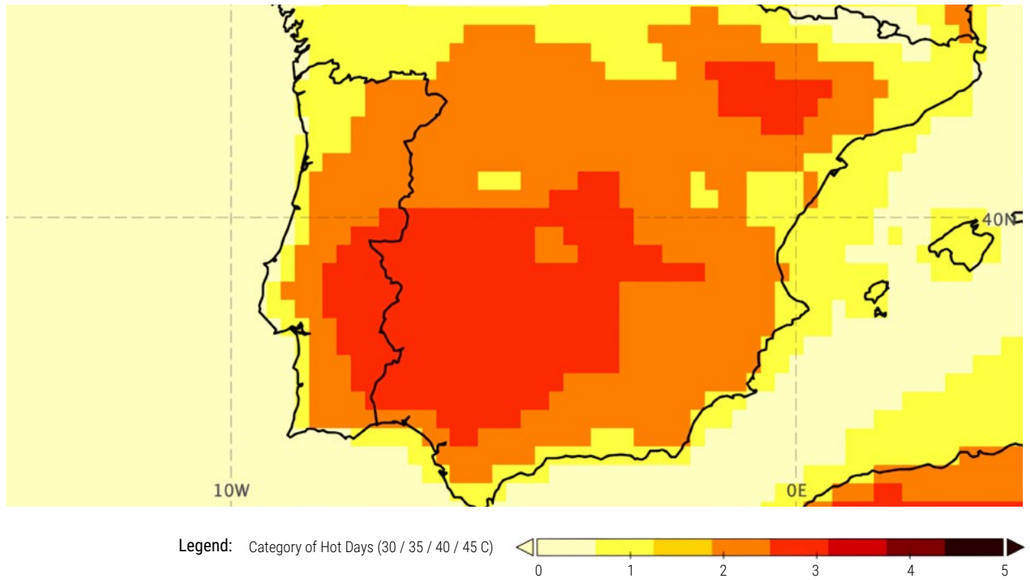
Figure 12. In summer 2022, the average air temperature was 0.98 °C above normal. A record over 20 years.



Source: Instituto Português do Mar e da Atmosfera (IPMA). (2022) Boletim climático Portugal continental junho 2022. Available via

The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Figure 13. **Projections of hot days heat risk from 2020 to 2039 predict that more than half of Portuguese territory will experience dangerous temperatures, particularly in the southern part of the country**



Source: World Bank Climate Change Knowledge Portal," n.d.

The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Vulnerability: Who was affected and why?

The precise number of deaths associated with the heatwave cannot be directly determined. It can only be estimated by comparing the expected number deaths within the same period had the heatwave not occurred. For the July 2 to 18, 2022 heatwave, an excess mortality of 1,380 deaths is estimated. When considering all summer heatwaves in 2022, this figure increases to more than 2,401 deaths. Most heatwave-related mortality in 2022 occurring among citizens older than 65, especially those over 85.

There is no disaggregated data regarding the regional impact of the heatwave from July 2 to 18, 2022. However, based on analysis of past heatwaves, the highest increases in mortality were observed in Portugal's inland areas. In these regions, the heatwave was more persistent, and the moderating effect of the sea on temperature was not felt. Despite warnings from health and civil protection authorities, the persistence of the heatwave in inland areas likely contributed to the mortality pattern, as these regions typically have older citizens, many of whom live alone and are isolated. Buildings in these areas were not well-prepared to cope with extreme heat, especially in rural areas. In addition, access to media information and proximity to healthcare facilities were less developed than in large urban coastal areas.

The heatwave also had significant economic impacts, particularly in agriculture, which accounts for more than 60 percent of drought-linked losses. From 1980 to 2023, these were worth about around €200 million each year.[67] Climate-related economic losses in Portugal amounted to €764 million in 2022 alone,[68] with projections indicating an increase in the future. Extreme weather events also have cascading effects on agricultural economics. Vulnerable sub-sectors include non-irrigated cereals (such as maize), fruit trees, perennials, tubers in regions with heavy precipitation extremes, and livestock reliant on green fodder.[69]

67 UNFCCC, 2021
68 EuroStat, 2022
69 Devot et al., 2023

Resilience: what factors limited the impacts?

The 2022 heatwave in Portugal highlights the importance of having "the right mindset" to prevent disasters. In developing its legal frameworks, Portugal has placed special emphasis on preventive strategies, aiming to make them more seamless with response operations and acknowledging the historical imbalance between the two. An example of this mindset is seen in Portugal's spatial planning and land-use policies, which integrate risk management to build resilience against heatwaves and other hazards. This case study also highlights the benefits of "good governance", a key factor in disaster avoidance.

A 2019 European Commission Peer Review report noted that "the Portuguese civil protection system is constantly looking for improvements", with a process in which "all actors are involved". This reflects a "shift in focus from response to prevention" with "awareness and willingness to fill the remaining gaps".

Following major heatwaves in 1981 and 1991 and 1991, which caused an estimated excess mortality of about 1,900 and 1,000 deaths respectively, Portugal established the Ícaro heat–health warning system in 1999. Ícaro provides daily heat-related mortality predictions to heat–health action plan practitioners, who then issue protection recommendation based on these advisories.[70] Ícaro's data complements meteorological information.

Portugal has implemented a National Risk Assessment, a National Strategy for Disaster Risk Reduction, adopted in 2018, a National Platform for Disaster Risk Reduction, and various sectoral mechanisms aimed at risk reduction. The 2004 Contingency Plan for Extreme Adverse Temperatures sets strategic guidelines for risk management and public communication, coordinated by the General Directorate for Heat, with specific roles for health and civil protection authorities. Measures include increasing risk information to vulnerable groups, reinforcing health and social care structures, and activating temporary acclimatized shelters.

The National Health Service (SNS) operates a contact centre (SNS 24) that provides guidance for non-emergency health problems. Information on heat protection is available on the SNS 24 website and many local government websites during heatwave alerts. Annually, the Health Ministry prepares a contingency plan for extreme temperatures to prevent adverse health impacts, providing timely information to local authorities for risk assessments and corrective measures.

Municipal and intermunicipal climate action plans also address the impacts of heatwaves. Schools follow guidelines for risk education, developed by the Civil Protection Authority, the General Directorate of Education, and the General Directorate of School Establishments. This reference document offers guidance and showcases best practices for teaching risk-related subjects.

Wildfire near houses in Povoa de Lanhoso, Braga, Portugal

Source: Shutterstock

70 Leite, 2020

STEP 2- Future trends:

This section looks at key root causes or emerging issues identified above and provides a snapshot of potential 'business and usual' trends where action now could prevent or reduce disasters in the future.

People

- Portugal has one of the world's oldest populations in the world.[71] Between 2011 and 2022, the percentage of people in Portugal aged 65 or over increased from 19.2 to 24.0 percent.[72] People over 65 make up nearly 30 percent of Portugal's adults, and this figure is expected to rise to 59.9 percent by 2035.[73]

- In Lisbon, annual heat-related death rates may increase from 5.4 to 6 per 100,000 people in 1980-1998, reaching from 8.5 to 12.1 by the 2020s. Without action, this number could potentially reach a maximum of 29.5 by the 2050s.[74]

Planet

- By the end of the 21st century, Portugal could experience as many as 8-10 heatwaves each year.[75] Under extreme climate scenarios, temperatures could rise by as much as 5°C by 2100, with the greatest increases expected in the northeastern interior regions.[76]

- Rural areas cover more than 90 percent of Portugal's mainland territory, with forests being the dominant land cover. This widespread rural landscape makes nearly all of Portugal's mainland territory vulnerable to wildfire risk. The growing risk of wildfires in Portugal result from a combination of factors, including changing land-use and management practices, shifting vegetation cover, and climate change.[77] From 1960 to 2021, Portugal's rural population decreased from 5.7 million to 3.4 million, or from 65 percent to 33 percent of the total population.[78] This decline has reduced agricultural plots, which can act as fuel breaks, as well as managed forests, leading to the accumulation of fire prone vegetation around rural settlements.[79] Additionally, rural land abandonment and the aging rural population have reduced the number of people available to help contain and suppress wildfires when they occur.

Prosperity

- The Portuguese agricultural sector is expected to face significant challenges from heatwaves, which are likely to reduce crop yields and animal productivity due to heat stress. This poses a threat to food security and economic stability.

- In southern Europe, potential crop yields could decline by more than 10 percent under a 2°C warming scenario. Climate change could further restrict the availability of water for irrigation, with yield declines of over 20 percent projected for all European Union countries. In Portugal, crop losses could reach up to 80 percent. Without market adjustments, grain maize production may become unviable in areas facing water scarcity and significant decreases in precipitation.[80]

71 Population Reference Bureau, 2020
72 Portugal National Statistics Institute, 2023
73 Portugal National Statistics Institute, 2024
74 Casimiro et al., 2006
75 Pereira, 2017
76 IPCC, 2018
77 OECD, 2023
78 World Bank,2024
79 Nunes, 2012; Nunes et al., 2016
80 Joint Research Centre, 2020

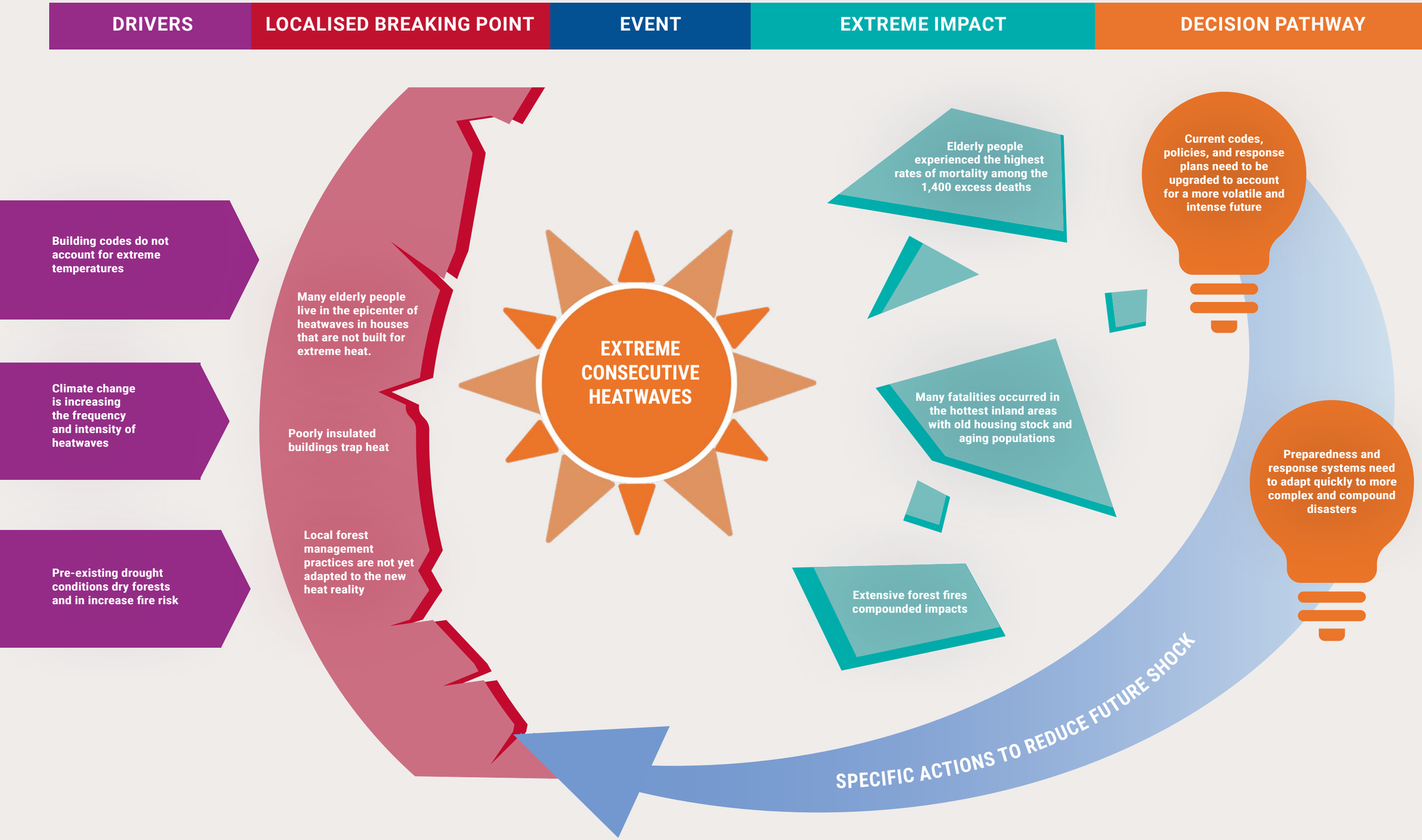
STEP 3- Forensic learning

This section aims to encourage dialogue around the forensic analysis to foster improved decision making. The areas for consideration below are envisaged as an input to stimulate in-country discussion and action plan on future disaster prevention and enhanced disaster risk management.

	People	Planet	Prosperity
Learning from the past	Extreme temperatures severely impact public health and safety, particularly among the elderly and vulnerable populations Only 17 percent of Portuguese homes have air conditioning, leaving the majority without this essential cooling system Portugal's population is one of the oldest in the world.	Heat-waves are most intense in inland areas which lack the cooling coastal winds. Heat-waves often occur at the same time as forest fires, having long term negative impacts on ecosystems.	Agriculture accounts for 2.7 percent of the national GDP and employs 5.8 percent of Portugal's national workforce.81 Urban heat islands intensify the effects of heatwaves in Portuguese cities. They lower productivity and increase health risks. Heatwaves have significant impacts on agriculture, leading to significant economic losses and threatening food security. Agricultural losses account for more than 60 percent of drought-linked losses.82
Resilient features	The national health services provide continuous information to the public and government offices.	The Portuguese civil protection system is well-developed and has a culture of continuous learning. A focus on systems helps disaster prevention as well as response.	European Union and national funds support farmers to restore agricultural productivity. Accurate data and technology played a critical role in monitoring and institutional response to the event.
Actions from the present for the future	Preparedness for future heat events is essential. It needs to be tailored towards particularly at-risk groups including the elderly, children, and homeless people. Maintaining public awareness of heat stress needs to cover both local populations and tourists.	Building codes and other incentives can encourage the construction of more sustainable buildings to improve energy efficiency and reduce the need for air conditioning. Implement measures to prevent and control forest fires, including the prohibition of campfires and increased surveillance in forest areas. Promote the planting of trees in urban areas to increase shade and reduce the heat island effect. Promote the cultivation of plant species that are resistant to heat.	Offer training programs and technical assistance to farmers on techniques for managing crops and livestock under extreme heat conditions. Invest in the construction and improvement of efficient irrigation systems, such as drip irrigation, to enhance crop resilience to high temperatures. Establish emergency funds to assist farmers affected by heatwaves, compensating for crop and livestock losses.

81 European Commission, 2023
82 UNFCCC, 2021

Portugal heatwave / 2022



Indonesia wildfires / 2023

Case Studies No 6

Forest fire that occurred in Kalimantan, Indonesia, on August 06 2023

Source: Shutterstock

STEP 1- Understanding the disaster DNA

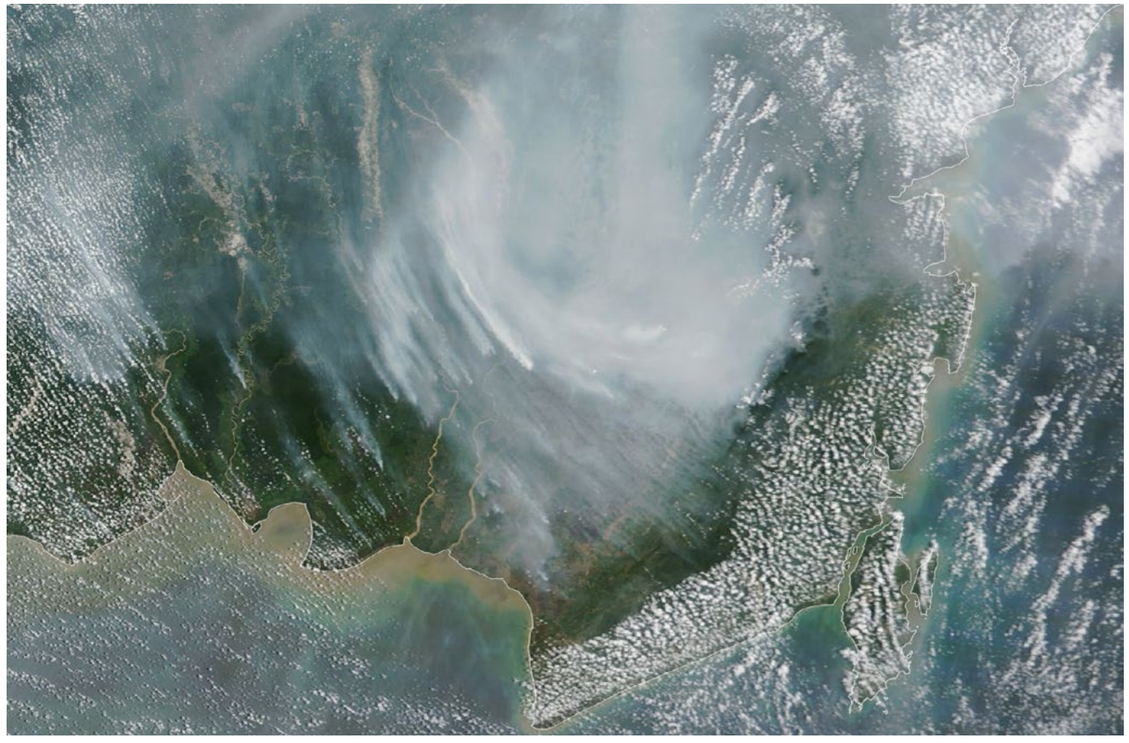
What Happened?

In 2023, Indonesia experienced a significant surge in wildfires, with the total area burned reaching 1.16 million hectares (2.87 million acres), a fivefold increase from 2022. This dramatic rise in fires was largely attributed to the El Niño phenomenon, which caused prolonged dry conditions across the region.

Human activities contribute to 98 percent of all fires, primarily due to social and cultural factors, including economic needs. Fire is a cheaper and easier method to clear land for crops, particularly oil palms.

When Indonesia's forests burn, particularly on peatlands, they release large amounts of smoke and pollutants into the air, posing serious health risks to the populations of Indonesia and Southeast Asia. The burning also has global implications, impacting the world's fight against climate change and biodiversity loss. Indonesia is one of the world's top ten countries in terms of forest area. It also hosts the world's third most significant variety of tree species.

Figure 14. The 2023 fires primarily in Kalimantan and Sumatra regions caused the loss of 13,260 hectares of primary forest, largely due to social and economic factors

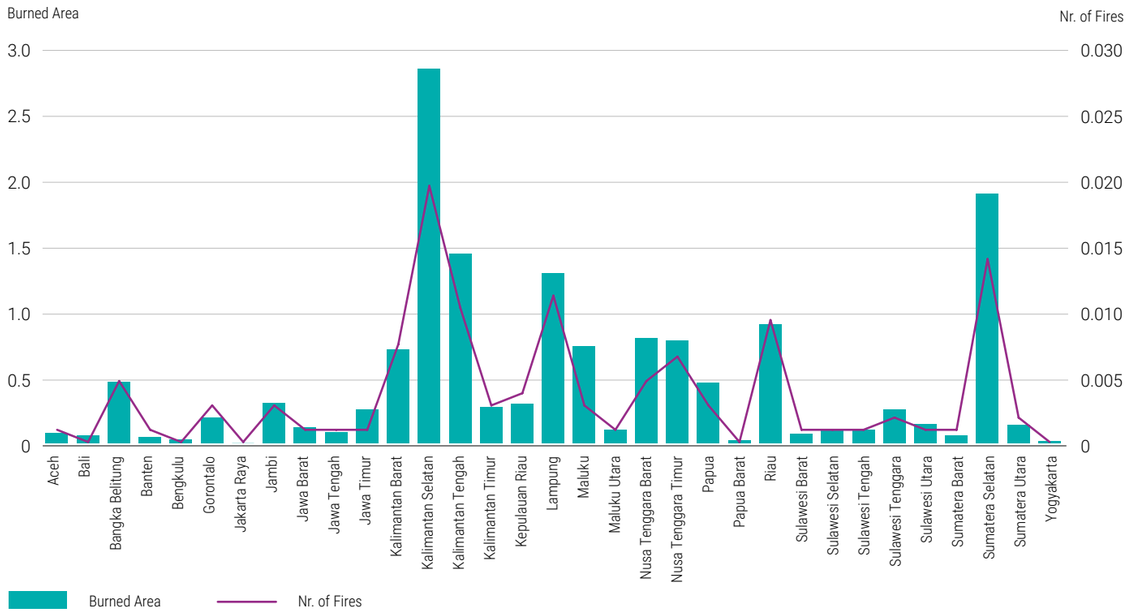


Source: NASA (2023), landsat image gallery.

Wildfire, Indonesia

Source: Flicker

Figure 15. **Shows the average size of burned areas per region per year as well as the average number of fires for the period 2002-2022**



Source: Global Wildfire Information System" n.d. , 2023

Exposure: Where was damaged concentrated?

The most affected provinces included South Kalimantan, Central Kalimantan, and South Sumatra, with extensive areas of land and peatlands caught fire. Between January and September 2023, the Ministry of Environment and Forestry identified 2,608 hotspots, nearly six times the 441 hotspots during the same period in 2022.

Most of the burning occurred in scrubland and degraded forest areas rather than intact forests, resulting in lower greenhouse gas emissions than in 2022. However, the fires still destroyed 13,260 hectares (32,800 acres) of primary forest.[83] Key drivers of deforestation in Indonesia include illegal logging, "slash and burn" practices to prepare land for oil palm plantations, and low-grade nickel mining. Various political and socio-economic factors influence land development, which, while helping to lift people out of poverty, also causes complex environmental and social impacts, such as smoke and air pollution.

Kalimantan, one of Indonesia's largest peatland regions, experienced the highest rates of burning and the most repeated fire incidents, indicating a shift from extensive to recurrent fires. The fires severely degraded air quality in the cities of Kalimantan and Sumatra, with air pollution levels rapidly reaching very unhealthy levels due to the increased hotspot counts. While wildfire impacts are intense for communities near forest areas, the haze travels across Southeast Asia. In 2023, Jakarta's air pollution levels were arguably the worst since 2019, consistent with a long-term trend of unhealthy air quality. Over 29 million people in the Jakarta Metropolitan Area were exposed to unhealthy air for more than half of the year. Concentrations of Particulate Matter that is 2.5 microns or less in diameter (PM2.5) remained in the "unhealthy" range from June to the end of the year, equivalent to 8 to 10 times the 2021 WHO Air Quality Guideline.

Besides health, the wildfires and related smog also impacted transportation (flights, shipping and road travel), and tourism. They increased the production of ozone, acid rain, and greenhouse gases, reducing quality of life, biodiversity and plant photosynthesis by obstructing solar radiation.[84]

83 Global Forest Watch, 2024(a)
84 Uda et al., 2019

Vulnerability: Who was affected and why?

Besides the loss of life and property, nearly 10 million children, particularly in Kalimantan and Sumatra, were affected by the pervasive air pollution from wildfires and peatland fires in 2019, leading to school closures and depriving children of learning opportunities.[85] Studies show that infants born to mothers, exposed to high pollution levels during pregnancy, face increased risks of complicated births and growth-related issues. Incidences of foetal and infant deaths were significantly higher in economically disadvantaged areas than in the wealthier regions.[86]

Poverty drives the use of fire for agricultural development in Indonesia, with less developed and more remote villages being more likely to burn.[87] Addressing this issue requires solutions to tackle existing poverty.

The impact of forest fires and haze is particularly significant for vulnerable communities, especially those with chronic risk factors. Research shows that while young men quickly recovered from the effects of haze, the impact on older adults persisted until the haze subsided.[88] Prime-age women also experienced health effects for several months after the haze had cleared.

Fire directly impacts and destroys biomass, organic matter, plant composition, and diversity. It affects the soil's physical and chemical properties, leading to loss of soil structure, reduced porosity, increased pH, threats to endangered species, and changes in habitat structure and species composition.[89] The fires in 2015 alone resulted in the loss of over 760,000 hectares of Indonesian forests.[90]

85 UNICEF, 2024
86 Chakrabarti, 2021
87 Edwards et al., 2020
88 Frankenberg et al., 2005
89 Jhariya & Raj, 2014
90 Global Wildfire Information System (GWIS). Accessed March 23, 2024 via https://gwis.jrc.ec.europa.eu

A local man holding a sprayer and extinguishing fire on a burning forest in Kalimantan, Indonesia, August, 6th 2023

Source: Shutterstock

Resilience: what factors limited the impacts?

The Indonesian government continues its efforts to limit the burning of forest and land for commercial purposes. While this is challenging across such a large territory, several key measures have helped to limit the impacts of the 2023 wildfires.

Indonesia's regulatory interventions have been more effective in reducing forest fire incidents than in countries like Russia, Brazil, Canada, and the United States. These regulations generally fall into four main categories: fire management, forest exploitation and management, disaster management, and decentralization.

Since the extensive forest fires of 1997–1998, Indonesia has strengthened its regulations on wildfires. Although the use of fire is significant for livelihoods and cultural practices, especially in Indigenous communities, the enforcement of fire bans has been criticized because they disproportionately target traditional farmers. These groups have often been respecting local customs, while major corporations have had a larger environmental impact.[91]

The government takes direction action when significant fires are linked to suspected legal breaches. The Ministry of Environment and Forestry appoints expert witnesses to gather evidence for legal proceedings, focusing on accountability. The government supports multilevel operations, facilitates fire care community groups, provides technical training, and conducts public awareness campaigns on forest fires and prevention. However, potential gaps remain, including inefficient impact assessment methods, insufficient education, and weak connections between state institutions and communities.

Indonesia has garnered global support, established sub-directorate bodies, conducted public education initiatives, enforced environmental taxes and fines, and engaged NGOs and international entities to address cross-border smog and haze pollution. The Ministry of Forestry patrols forest areas, uses satellite imagery and watchtowers to prevent fires. However, inconsistent regulations have hindered the effective prevention and management of fires.[92]

The use of incentives can enhance fire prevention and reduction efforts, ensuring sufficient fire-fighting capacities, compulsory insurance, and deposit schemes, for example. The Indonesian government continues to attempt regulation and other interventions to control and limit forest and land burning for commercial gain, but this remains a challenging task across such a large territory.

Recent haze and smog periods have highlighted the health damage that forest burning can cause across Southeast Asia. To lift people in these areas out of poverty and provide better livelihood opportunities, it is crucial to make the right investments at the right time. This involves valuing unspoilt nature and providing local communities with viable alternative livelihood options, rather than encouraging land to be slashed and burned for commercial purposes. This case study highlights the importance of making "the right investment" to prevent disasters, whether by governments, private sector corporates, or smallholder farmers.

91 Fajrini, 2022
92 Herawati and Santoso, 2011

STEP 2- Future trends

People

- Most fires in Indonesia are linked to ownership claims or traditional agricultural methods like slash-and-burn land clearing.[93] This trend is likely to continue in the near future. In Kalimantan, the Indonesian part of Borneo, about one third of the tropical forests have been cut down in the past few decades.
- In 2018, some 53 percent of Indonesians were living in poverty, defined by the World Bank's international poverty line. For many farmers, "slash and burn" is the fastest, easiest, and most cost-effective way to clear land, providing access to food and income.
- Smog associated with these fires will continue to harm the health of Indonesians. Evidence shows that cumulative exposure to smoke particles adversely affects lung function and blood pressure.[94]

Planet

- Indonesia will experience higher fire risks due to rising temperatures, even during non-drought years, driven by high evaporation rates in fragmented forest.[95]
- A recent study predicts that as climate change worsens and deforestation intensifies, the risk of forest fires will continue to rise. The combined effect of climate change and deforestation in Borneo significantly increases fire risks. High levels of carbon dioxide in the atmosphere, coupled with deforestation-caused dry conditions, further fuel these fires.[96]
- Indonesia is projected to lose an additional 13 percent of its forest cover in the next decade,[97] exacerbating biodiversity losses by destroying critical biomass, altering plant compositions, and degrading soil properties.

Prosperity

- Fires in Indonesia cause significant economic damage, estimated at $16 billion each year. This exceeds the value of palm oil exports in 2014, around $8 billion.[98] Prolonged haze exposure also hampers plant productivity, further crippling agriculture including the palm oil sector.
- Reducing the frequency of forest fires by just 1 percent could generate a net benefit of between US$17 million and $145 million. Even the lower estimate of health benefits would exceed the agricultural gains from continued forest fires. However, as Indonesia's economy grows, air quality is likely to deteriorate further.[99]

93 Tacconi, 2023
94 Marlier, 2021
95 IPCC, 2022
96 Davies-Barnard et al., 2023
97 Chandra et al., 2024
98 World Bank, 2016
99 Rahman, 2024

STEP 3: Forensic learning

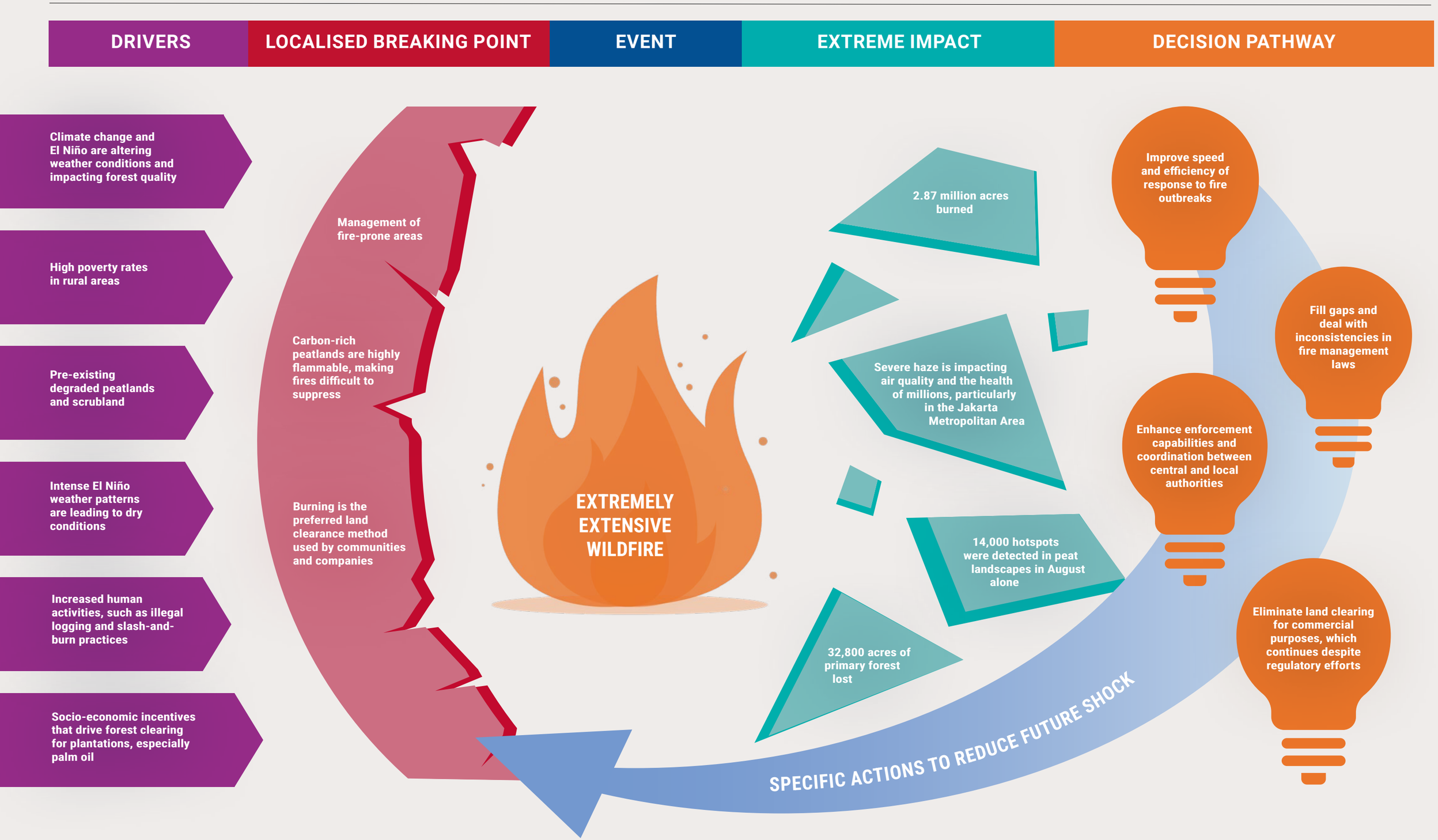
This section aims to encourage dialogue around the forensic analysis to foster improved decision making. The areas for consideration below are envisaged as an input to stimulate in-country discussion and action plan on future disaster prevention and enhanced disaster risk management

	People	Planet	Prosperity
Learning from the past	Without serious and systematic prevention, fires that are started intentionally can get out of control. Local fire management structures do not have enough capacity to contain fires once they start. Fire events produce pollution, which impacts health, particularly in vulnerable populations. When pregnant mothers are exposed to high pollution, they and their infants are more likely to suffer birth and other complications. At the current scale, traditional slash and burn practices are damaging ecosystems.	In 2015, intense fire activity burned more than 2.5 million hectares. Carbon-rich peatlands are particularly vulnerable to fires. In August 2023, more than 14,000 hotspots were detected in peat landscapes. El Niño events usually lead to drought conditions in Southeast Asia, increasing the likelihood of wildfires. Land development increases deforestation. It also increases the risk of forest and peat fires.	Fire is a cheap and easy method to clear land. However, human activities have been a major cause of fires, especially activity related to business such as the expansion of oil palm plantations. Transboundary haze has economic impacts. It disrupts transport and tourism, particularly in years with severe haze. Incentive mechanisms can enhance the effectiveness of fire prevention and reduction.
Resilient features	Indonesia has facilitated fire care community groups, provided technical training, and conducted awareness campaigns for the public on forest fires and their prevention. Fire bans have been criticized because they disproportionately target traditional farmers who are adhering to local wisdom. Major corporations have a larger environmental impact.	Indonesia has introduced policies and measures to protect and restore carbon-rich peatlands, reducing the area affected by fires compared to past severe fire seasons. Despite regulations, forests continue to be cleared for oil palm plantations and land development. This exacerbates smog and haze hazards.	Indonesia's efforts, including regulation and community awareness campaigns, have helped to reduce the number of fire incidents over the years. The country is trying to balance economic development with environmental sustainability. Indonesia's frequent regulatory interventions have reduced the number of forest fire incidents.
To inform the future	Increase awareness and provide technical training for local communities on fire prevention and the dangers of slash-and-burn practices. Promote agricultural practices that respect local wisdom while reducing fire risk. Teach other methods that encourage environmental conservation Improve healthcare in vulnerable regions impacted by air pollution.	Accelerate efforts to restore degraded peatlands with endemic vegetation that have a low oil component and therefore, low risk that when burned, it will expand further. Implement strict protection measures to prevent illegal land cleaning. Implement comprehensive forest management that focuses on long-term ecological health and sustainable development.	Offer alternatives and financial support to farmers, who farm sustainably. Discourage fire land cleaning. Develop economic transition programs in rural areas such as agroforestry and ecotourism.

Borneo, Indonesia, 3 August 2023, a firefighter extinguishing a forest fire

Source: Shutterstock

Indonesia wildfires / 2023



Canada wildfires / 2023

Case Studies No 7

Wildfire interior, British Columbia, Canada

Source: Flickr

STEP 1- Understanding the disaster DNA

What happened?

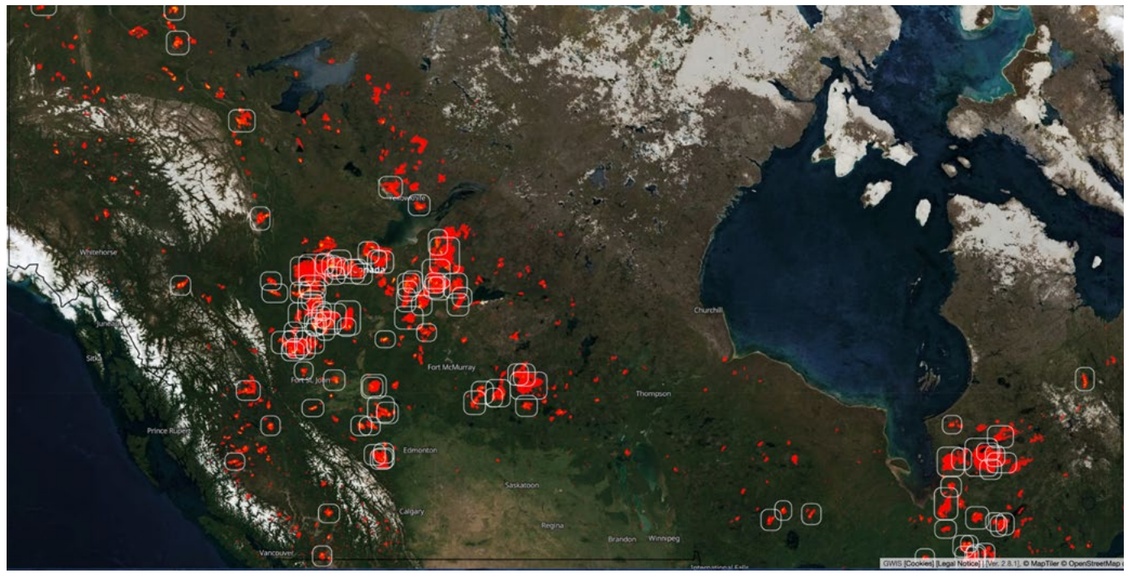
The 2023 wildland fires across Canada were unprecedented. In Alberta, the fires became out of control in late spring, followed by large wildfires in Quebec, Nova Scotia, Northwest Territories, and British Columbia as the summer progressed.

No civilian fatalities were recorded, but the fires did kill eight firefighters. The number of secondary injuries remains unknown. The wildfires burned through 15 million hectares, an area larger than Greece and double the previous record from 1989.[100] Some 232,000 Canadians were forced to evacuate their homes, and, in some areas, skies were filled with smoke for weeks.

The fires blanketed much of Canada, but also spread smoke to the United States and Europe, impacting air quality standards and posing risks to human health.

The loss of tree cover from these fires released about 3 billion tons of carbon dioxide into the atmosphere, nearly four times the emissions from aviation in 2022.[101] Much of this carbon will eventually be reabsorbed as Canada's forests regrow, but it will take decades to sequester the carbon emitted in just a single year.

Figure 16. The extent of the forest fires in Canada in 2023 covered a large part of the east of the country, as well as the northern region of Quebec and the northwest of the country

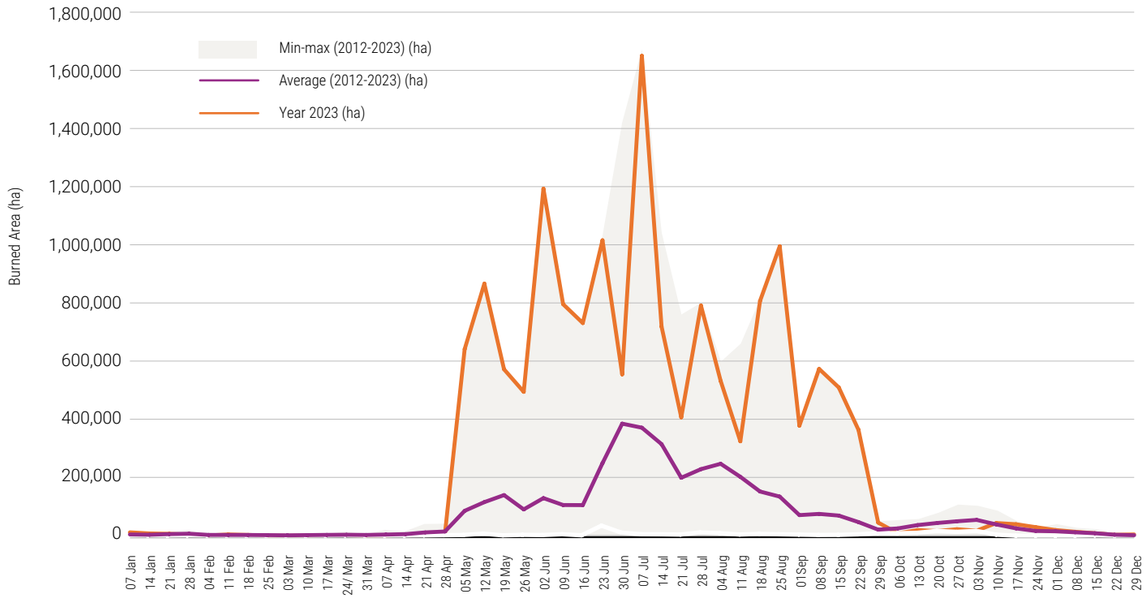


Source: Global Wildfire Information System (GWIS), Map Tiler, Open Street Map

The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

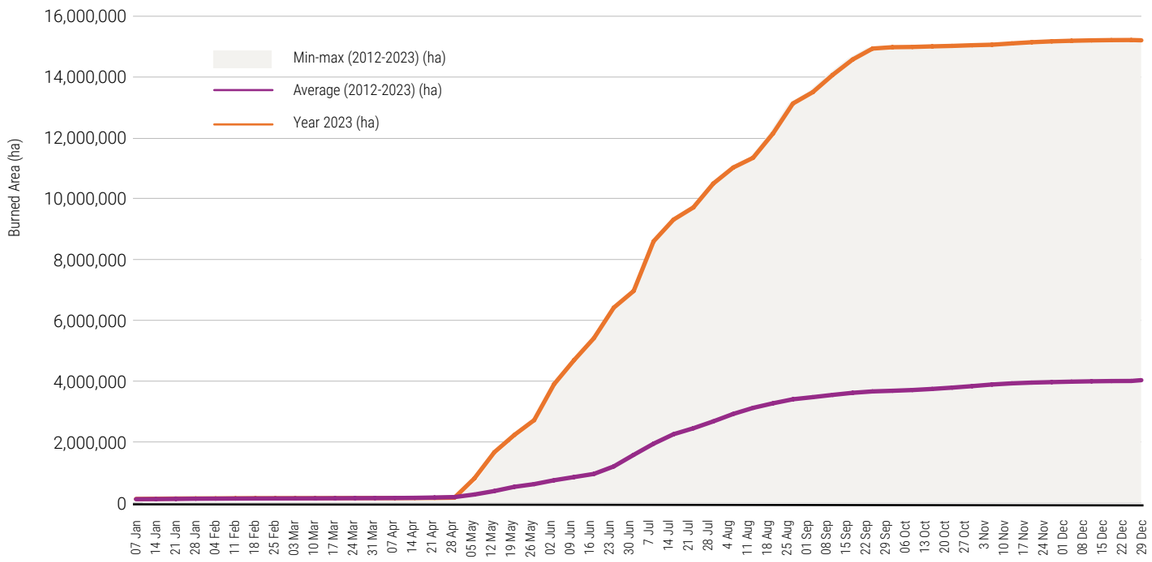
100 Government of Canada, 2023(a)
101 International Energy Agency, 2023

Figure 17a. **Fires in 2023 were almost four times as intense as the average for the period 2012-2023**



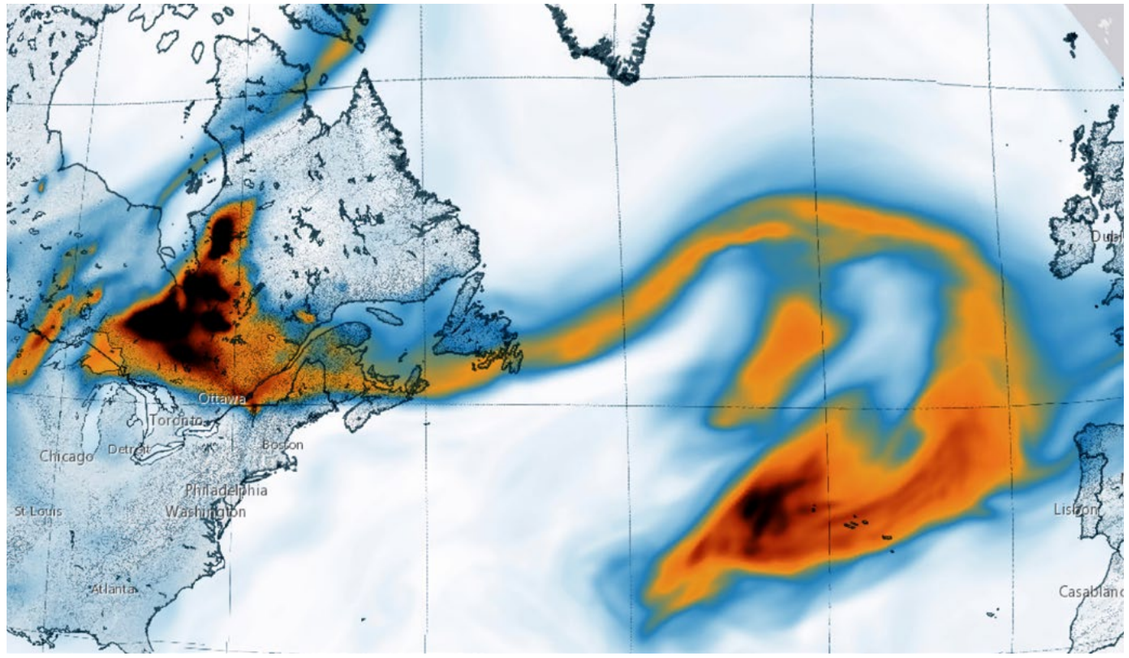
Source: Global Wildfire Information System (GWIS)

Figure 17b. **The nearly exponential increase began in mid-March 2023 and leveled off at the end of September of the same year**



Source: Global Wildfire Information System (GWIS),

Figure 18. **The North Atlantic winds carried particles from the Canadian fires to Europe**



Source: UNDRR with data from NASA Earth Observatory images and ESRI Canada

The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

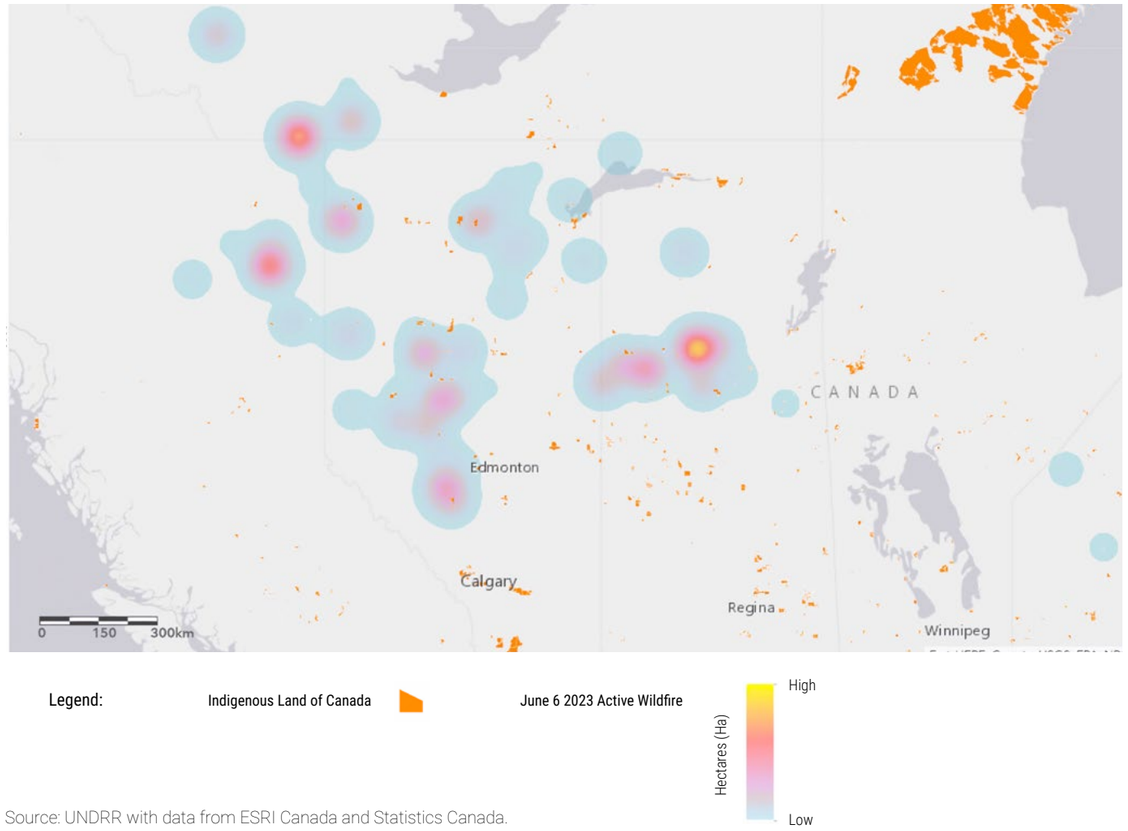
Exposure: Where was damage concentrated?

Canada's 2023 wildland fires were bigger than ever in terms of their scale, range, area burned, and impact. Starting in May, the fires sometimes consumed more than 1.6 million hectares in a single week. The widespread nature of the wildfires meant that they affected more people than ever before, with an estimated 232,000 people evacuated.[102]

Many of those affected lived in rural or semi-rural areas near cities, including growing numbers of rural recreation properties, critical infrastructure, and isolated communities. This expansion increased the number of people and industries exposed to the impacts of wildfires.

102 Piyush, 2024

Figure 19. The scale of Canada's June 2023 fires meant that they significantly affected the small indigenous communities scattered throughout the central territory of Canada and, to a lesser extent, those in the northern part of the country



Source: UNDRR with data from ESRI Canada and Statistics Canada.

The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

In terms of firefighting difficulty and likely fire duration, wildfire conditions in 2023 were the worst ever recorded in Canada for the period 1980-2023. In response, twelve countries and the European Union sent a total of 5,500 international firefighters, support staff, and equipment through the Union Civil Protection Mechanism.5

The severity of the fires heightened concerns about secondary impacts, including damage to watersheds, habitat loss for animals, potential flooding due to hydrophobic soils and land cover removal, as well as the loss of cultural and recreational landscapes. The Global Report on Internal Displacement calculated that Canada accounted for 43 per cent of worldwide wildfire displacements in 2023.

Canada's changing climate is also contributing to large insect infestations, which increased tree mortality between 2000 and 2020 and heightened the risk of wildfires.9 Changes in fire ignition patterns have also played a role.

Canada's 2023 wildfires emitted nearly 480 megatons of carbon, almost five times the Canadian average for the past 20 years and accounting for 23 percent of the world's wildfire emissions that year.[103] Additionally, some 10,700 kilotons of particulate matter (PM2.5) were emitted, 5.3 times the annual average. Pollutants from Canada's wildfires were injected high into the atmosphere, reaching countries in western Europe too.

103 European Union, Copernicus Atmosphere Monitoring Service (CAMS), 2023

Table 4: shows how Canada's Indigenous communities experience significantly higher levels of monetary poverty and housing vulnerability than the national average

Indicator	Overall	Women	Indigenous people (living off reserve)	Racialized population
Deep income poverty (Source: 2018 Canadian Income Survey)	1,181,675	185.312	100,102	not available
Unmet housing needs (Source: 2016 Census)	16,617,000	1,258,750	265,600	not available
Food insecurity (Source: 20117–18 Canadian Community Health Survey)	16,955,266	3,280,770	1,014,100	not available
Median hourly wage (Source: 2019 Labour Force Survey)	12,613,120	4,040,000	1,713,000	25,000
Relative low income (Source: 2018 Canadian Income Survey)	48,190,706	12,828,396	4,868,436,486	not available

Source: Government of Canada (2021b). Building Understanding: The First Report of the National Advisory Council on Poverty.

Vulnerability: Who was affected and why?

Multiple factors increase the risk of wildfires in Canada, including fire exclusion policies, land-use and forest management practices, population growth in the wildland-urban interface, fire management, and climate change.[104]

First Nations living on reserves are disproportionately impacted and the 2023 season was no exception. Some 80 percent of Canada's Indigenous communities are located in or near forests that burn frequently.[105]

Besides being more vulnerable to wildfires, these communities often have fewer resources to respond and recover. First Nations living on reserves account for just 1.2 percent of the Canadian population, but their evacuation rates during the 2023 wildfires were eight times higher than the general population.

The isolation of these communities further exacerbates their vulnerability, since they are often outside the jurisdiction of local firefighters and lack essential infrastructure such as all-weather roads. First Nations have expressed concern about being excluded from wildfire management mechanisms. One year after the 2023 fires, many Indigenous communities remain displaced.[106]

Canada's older adults, many of whom live in rural areas, are also at heightened risk during wildfires. Now outnumbering children and adolescents in Canada, they require more assistance during evacuations. The Canadian Statistics Office projects that by 2051, people aged 65 and over will represent 25 percent of Canada's population. Understanding the geographical distribution and vulnerabilities of Canada's aging population is crucial for wildfire management agencies as they prepare for and plan disaster responses.

104 Bush, 2019
105 Asfaw et al., 2019
106 Levy, 2024

Wildfires impact both physical and mental health, making them a risk to public health and well-being. While discussions around public health often focus on the acute and short-term impacts, the long-term effects of wildfires on populations and communities are expected to persist. Individuals who remain in place or who are not repatriated may face other long-term public health risks that are not fully addressed in this report..

In British Columbia, two wildfires caused losses exceeding CA$720 million, making them the province's most expensive extreme weather events on record.[107]

Resilience: what factors limited the impacts?

Canada's national and local governments are increasing their spending on wildfire prevention and mitigation, but these amounts are still small compared to the costs of wildfire suppression.

Despite disruptions to industries such as oil, lumber, and tourism, the Canadian economy has demonstrated a strong ability to recover from wildfires. Canada has proactively enhanced its economic resilience by investing in critical infrastructure such as roads, bridges, and communication networks. These efforts facilitate recovery and strengthen the economy's ability to withstand future wildfires.

Promoting economic diversification and sustainable industries is crucial for reducing reliance on vulnerable sectors. This diversification helps stabilize the economy and mitigate the broader impacts of wildfires, ensuring long-term economic stability.

The Canadian government's swift response and support for affected communities and industries demonstrates effective policy measures aimed at economic resilience. This support includes financial assistance, job creation initiatives, and long-term economic development plans. Infrastructure needs are addressed, and businesses receive the necessary support.

Canada's robust insurance programs and risk management strategies play a vital role in mitigating financial losses and supporting economic recovery. These measures help businesses and homeowners to recover quickly, minimizing disruptions to economic activities.

Bringing together all jurisdictions, including First Nations, and integrating policies and actions - from wildfire prevention to post-fire recovery - can fully incorporate local knowledge and priorities. Utilizing "good data" through dynamic land-use maps from earth observations can help identify communities at the wildland-urban interface. When combined with socioeconomic information and local or Indigenous knowledge, this data can help to assess wildfire risk and prioritize preventive actions. "Meaningful inclusion" enhances the impact of "good data" by fostering knowledge sharing among communities and local actors, helping to build a common framework for understanding how wildfires impact communities and developing potential solutions to prevent disasters.

Indigenous Services Canada is coordinating efforts to address wildfire management through new multilateral emergency management service agreements with First Nations as full and equitable partners. There is growing recognition that the revival and expansion of Indigenous fire knowledge and stewardship practices can help to improve biodiversity and reduce wildland fire risk to communities.

Indigenous knowledge is a key element in responding to the climate crisis. Recognizing this, the Canadian government has created a program through Crown-Indigenous Relations and Northern Affairs Canada to promote Indigenous climate leadership and low-emissions energy initiatives.[108]

107 Insurance Bureau of Canada, 2023
108 Government of Canada, 2023(b)

Canadian wildfires, Nova Scotia air quality after weeks of smoky siege

Source: Shutterstock

STEP 2- Future trends

People

- By 2050, 25 percent of Canada's population will be over the age of 65.[109]
- Currently 32 percent of First Nations reserves are in or directly adjacent to the wildland-urban interface, putting them at particularly high risk of forest fires.[110]
- Approximately 32.3 percent of land is classified as High fire risk, and 6.3 percent as Very high fire risk. Around 283,200 people live in areas at High fire risk, while 30,500 people live in areas classified as Very high fire risk.
- Indigenous on-reserve communities are especially vulnerable to wildfire impacts. An estimated 18.9 percent of people living in Indigenous reserves reside in areas at higher risk of fire, compared to only 2.4 percent of the non-reserve population.
- Communities in large urban areas have generally been spared displacement due to wildfires, but this trend shifted during the 2023 wildfire season, when nearly half of the recorded displacements took place in urban areas.[111]
- Canada's population was 22 million in 1971, growing to 38 million in 2021. It is projected to reach between 44.4 million and 70.2 million by 2068. With population growth, encroachment into forested landscapes, and climate change, wildfire disasters will likely become more frequent and with more dramatic consequences. The social, physical and ecological losses will likely also increase.[112]
- Migration of First nation people away from their territories to urban areas is becoming more common.
- Smoke from wildfires impacts populations near the fire activity, as well as those at a distance due to the long-range transport of air pollutants. For 2013 to 2016 and from 2017 to 2018, annual premature mortality attributable to wildfire-related PM2.5 was estimated at 54–240 mortalities from short-term exposure and 570–2,500 deaths from long-term exposure, along with many cardiorespiratory morbidity outcomes.[113]

109 Statistics Canada, 2024
110 Erni et al., 2021
111 IDMC, 2024
112 Erni et al., 2024
113 Matz et al., 2020

Planet

- Canada is warming twice as fast as the global average. Its Arctic regions are warming nearly four times as fast.[114] Climate change more than doubled the likelihood of extreme fire weather conditions in Eastern Canada in 2023, including high temperatures, low humidity, and drought. It also made Québec's 2023 fire season around 50 percent more intense.[115]
- Each year, wildfires burn more than 2 million hectares of Canadian forest.[116]
- The 2023 fire season emitted almost 480 megatons of carbon, nearly five times the average for the past 20 years, accounting for 23 percent of the total global wildfire carbon emissions that year.[117]

Prosperity

- Economic losses due to forest fires are currently significant and may rise if current fire trends continue. Assistance funds average about CA$340 million per year in Canada, with CA$1.7 billion paid by the Disaster Financial Assistance Arrangements Program between 2016-2017 and 2020–21.[118]
- About 1,910,534 buildings in Canada are directly exposed to wildfires, with 6.4 percent classified as being at high to very high wildfire risk. Although these numbers are estimates, they provide a realistic measure of the potential socio-economic impacts of wildfires on Canadian communities. The past shows that a single fire event can destroy hundreds or even thousands of buildings, leading to direct and indirect losses that can total several billion Canadian dollars.[119]
- Fire smoke, an indirect exposure, poses risks to human health. The economic valuation of health impacts was estimated per year at CA$410 million to CA$1.8 billion per year for acute health impacts, and CA$4.3 billion to CA$19 billion for chronic health impacts between 2013 and 2018.[120]

114 Government of Canada, 2019; Rantanen et al., 2022.
115 Canadian Climate Institute, 2024
116 Government of Canada, 2024
117 Copernicus Programme, 2023
118 Public Safety Canada, 2022
119 Erni et al., 2024
120 Matz et al., 2024

STEP 3: Forensic learning

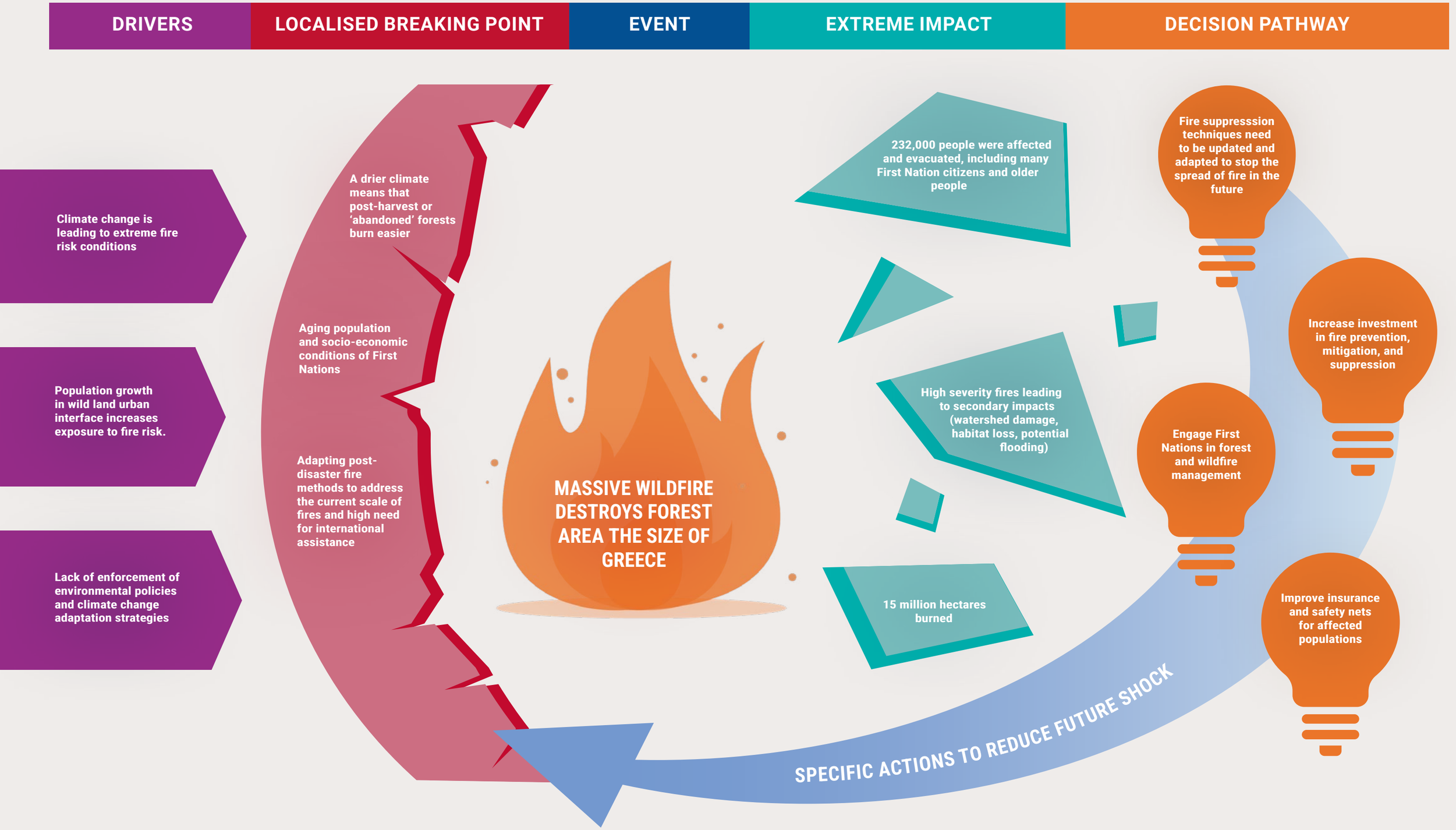
This section aims to encourage dialogue around the forensic analysis to foster improved decision making. The areas for consideration below are envisaged as an input to stimulate in-country discussion and action plan on future disaster prevention and enhanced disaster risk management

	People	Planet	Prosperity
Learning from the past	A growth in urban sprawl and demand for rural recreation are all associated with higher fire risk in Canada. Increased awareness is key to fire prevention. Wildfires disproportionately affect First Nations and older people. They reveal gaps in support and infrastructure for vulnerable groups.	Current fire control methods need upgrade to better contain the spread of major fires. In 2023, such wildfires burned about 15 million hectares (more than five times the annual average). The wildfire smoke reached the United States and Europe. It caused poor air quality that posed risks to human health. Global cooperation – including deployment of international firefighters - helped to contain the wildfires. Extreme weather conditions, land use changes, and forestry management increased the risk of wildfires.	The wildfires affected 232,000 people affected, of whom many were forced to evacuate. The wildfires also caused significant property damage and economic losses. Homes, businesses, and infrastructure were expensive to rebuild. Insurance claims were high. The fires also destroyed crops and livestock, leading to immediate losses for farmers and long-term impacts on agricultural productivity.
Resilient features	Indigenous Services Canada is coordinating efforts between jurisdictions, negotiating new emergency management agreements, with First Nations as full and equitable partners.	International support deployed. Adequate equipment such as hoses, pumps, and aircraft were also deployed.	Canada has demonstrated an ability to adapt and recover, minimizing long-term economic disruptions. Canada has swiftly addressed infrastructure needs and diversified economic activities. This helps to mitigate the broader economic impacts of such disasters.
To inform the future	Work with Indigenous communities to design and implement social services for fire impacted communities. Deploy advanced firefighting technologies and equipment for immediate fire suppression and containment. Develop policies that target support for older populations in remote locations. Work with health and toxicology departments to monitor and assess toxin levels and potential health risks from fire-related exposure.	Conduct rapid assessments of burned areas to identify the immediate environmental risks. These include soil erosion, water contamination and smoke clouds. Take immediate actions such as reforestation, public health instructions and soil stabilization. Ensure that wildfire and peatland-based emissions are included in Canada's carbon footprint reporting. Restore natural habitats to support wildlife recovery. Promote sustainable land-use practices that reduce fire hazards, including indigenous reserves and governance.	Provide financial assistance to businesses and individuals affected by the wildfires. Work in cooperation with insurance companies and establish emergency funds for households, small businesses and farmers. Diversify economies in affected regions to reduce dependency on vulnerable industries and agriculture, especially for Indigenous communities. Rebuild and upgrade critical infrastructure such as roads, bridges, and communication networks. Build resilience against future wildfires.

Aftermath of a forest fire, Jasper National Park, Alberta, Canada

Source: Shutterstock

Canada wildfires / 2023



Central America Drought / 2023

Case Studies No 8

Low level of water is measured by a gauge on the Cantareira Jaguari dam during a severe drought in Sao Paulo state, Brazil

Source: Shutterstock

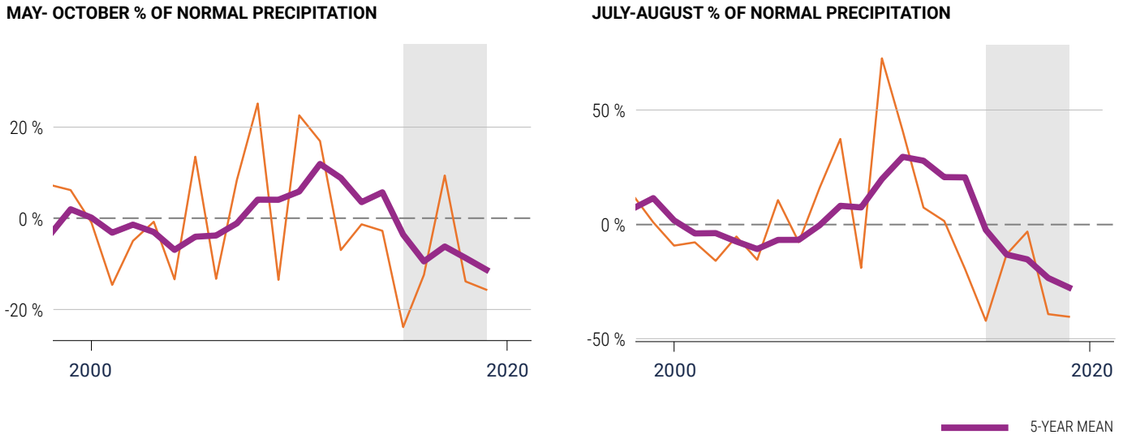
Step 1: Understanding the disaster DNA

What Happened?

Droughts have been a persistent hazard in Central America for more than 12,000 years, impacting ecosystems, life zones, and resource use. While these dry spells vary in size, duration, and impact, they have been handled in very different ways.

Since 1981, regional droughts have occurred roughly every seven years, lasting about a year and affecting an average of four countries each time. El Niño is often assumed to be a factor, but in fact it triggered only half of the regional droughts in this period.

Figure 20. Central America experienced a severe drought between 2015 and 2019, with the May-October rainy season seeing the lowest average rainfall on record (11.49% below average). This surpassed the previous driest period. However, the most significant rainfall deficits occurred during July and August, exceeding any other 5-year period by over 13%.



Source: Anderson, Talia G., Karen A. McKinnon, Diego Pons, and Kevin J. Anchukaitis. 2023. "How Exceptional Was the 2015–2019 Central American Drought?" Geophysical Research Letters 50 (21)

Climate change in Central America is predicted to make dry areas drier and wet areas wetter, while four of the seven Central America capitals are already experiencing significant reductions in rainfall. Environmental degradation, including water pollution from industrial and agricultural activities, worsens the situation even more. Growing deforestation rates, particularly in Honduras and Guatemala, compound the situation.[121]

Agriculture is highly sensitive to drought, and, in 2014, decreased and uneven precipitation caused significant damage. Between May and July 2014, for example, the amount of rainfall dropped throughout the Pacific region in some areas by up to 4 mm per day. Even one month of drought can cause crop loss, and in some countries, the July canícula, normally a two- or three-week dry spell, lasted for as many as ten weeks.

121 Global Forest Watch, 2024(b)

Exposure: Where was damage concentrated?

Central America faces structural challenges with its water security. Demand for water is highest in major cities, but most of these are located in places where supplies are historically lower. Often these densely populated areas are adjacent to regions of intensive agriculture, which also need plenty of water.

Farmers are also affected. Central America has more than 1 million households, who survive on subsistence farming. These are primarily in the Dry Corridor which spans more than 30 percent of the region. Drought impacts these farmers the most, causing malnutrition and reducing their opportunities to escape from poverty.[122]

Vulnerability: Who was affected and why:

Droughts in Central America disproportionately impact those with lower socioeconomic standing. Farmers, especially small-scale farmers, are particularly vulnerable due to limited resources for adapting to changing conditions. Similarly, those lacking access to clean water suffer greatly during droughts as existing infrastructure often struggles in dry periods. Vulnerability is closely linked to livelihoods and access to essential services.

Historically, the agricultural sector has borne the brunt of drought impacts, particularly small and medium producers. However, recent droughts have expanded their reach, affecting urban areas and industries. The Economic Commission for Latin America and the Caribbean (CEPAL) estimates that by 2100 potential production losses could reach up to 22 percent of Central America's agricultural GDP. Corn, beans, and rice occupy half of Central America's cultivated land. Studies incorporating soil degradation effects have predicted significant production losses for staple grains, with bean production particularly affected. Expected reductions are around 25 percent in Nicaragua, Guatemala, El Salvador, and Honduras. About 78.6 percent of agriculture in Central America is family-based, with an average 3.13 hectares of land per family. More than 60 percent of families use their production for subsistence.

In Guatemala, drought affects 70 percent of the country's landmass and the poorest 54 percent of the population, who account for half of all chronic malnutrition among children under age five, according to Guatemala's Food and Nutritional Security Secretariat, SESAN.[123]

Impacts are increasingly cascading. A 10 percent reduction in crop yields could lead to emigration by an estimated 2 percent of the population, for example. By 2080, climate change and related declines in agricultural productivity could induce 1.4 to 6.7 million adult Mexicans to emigrate.[124]

In August 2022, the Mexican President proposed to halt beer production in the northern part of the country due to a severe water shortage. This region, which includes the heavily populated city of Monterrey, is experiencing a drought that threatens the availability of water for domestic use. The brewing process requires significant amounts of water, and studies suggest that climate change is posing a global threat to the beer industry[125].

Water scarcity disrupts industrial operations and increases energy costs in countries reliant on hydropower. Access to essential public services in rural areas and many urban areas also needs improvement. Basic infrastructure, healthcare, and education are insufficient, perpetuating cycles of poverty and hindering human development. Informality is high in labour markets, with limited formal employment opportunities and social protection, especially for youth and women

Drought-related disasters in Central America would be less severe with reduced poverty, better income distribution, and higher-quality labour markets. Poverty and inequality have been constant challenges in the region for the past 50 years. In rural areas, poverty is closely linked to subsistence agriculture, while in urban areas, it manifests through lack of access to formal jobs, adequate housing, and essential services like clean water, sanitation, and education.

Floods and droughts increased poverty levels by 1.5 to 3.7 percent between 2000 and 2005.[126] Institutional weaknesses further exacerbate the problem. Aging water treatment and distribution infrastructure in dry regions leads to significant water loss, hindering access, particularly in rural areas. Closing the investment gap in the water and sanitation sector is crucial for improving drought resilience.

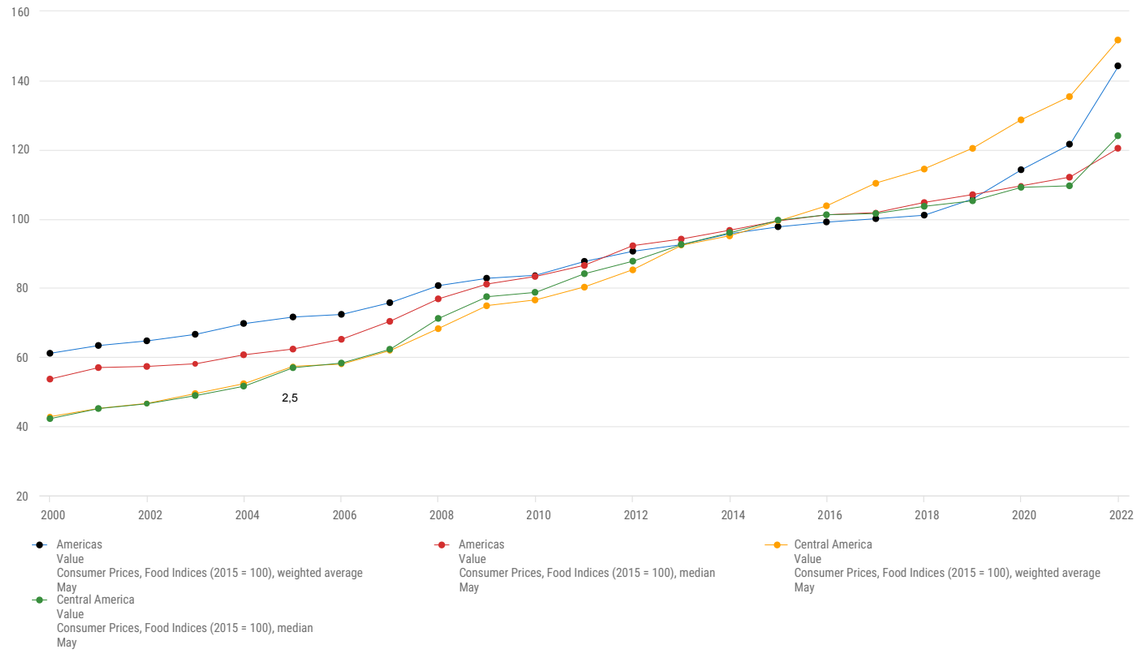
In 2022, inflation in Latin America and the Caribbean fluctuated between 3.6 and 6 percent, driven by high international commodity prices, production, and transportation costs. Currency depreciations, weather events, and insecurity pushed prices higher, especially in Haiti.[127]

A maize farmer with a handful of dry soil

Source: 2012CIAT/NeilPalmer

122 World Bank, 2014
123 Ibid.
124 Feng, 2010

Figure 21. Central America experienced a severe drought between 2015 and 2019, with the May-October rainy season seeing the lowest average rainfall on record (11.49% below average). This surpassed the previous driest period. However, the most significant rainfall deficits occurred during July and August, exceeding any other 5-year period by over 13%



Source: Government of Canada (2021b). Building Understanding: The First Report of the National Advisory Council on Poverty

125 Valladares, 2024
126 Rodriguez-Oreggia et al., 2013
127 FEWS NET, 2023

Table 5. **All projections for 2030 indicate that Central American countries will face significant economic and social consequences from climate change and the increasing carbon intensity of the environment**

	Economic cost				Human impacts					
	Climate change impacts		Carbon intensity impact		Climate change impacts and carbon intensity impact		Climate change impacts		Carbon intensity impact	
	% GDP				Mortality		Persons affected			
	2010	2030	2010	2030	2010	2030	2010	2030	2010	2030
El Salvador	3.6	7.2	0.5	0.8	1 500	1 500	100 000	150 000	45 000	60 000
Guatemala	2.9	5.8	0.8	1.2	3 500	5 000	1 100 000	1 200 000	150 000	250 000
Honduras	4.6	9.0	1.5	2.5	2 500	3 000	150 000	250 000	100 000	150 000
Nicaragua	6.3	11.7	2.4	4.3	1 500	2 000	95 000	200 000	55 000	65 000

Source: Economic Commission for Latin America and the Caribbean, "Cambio Climático en Centroamérica, Impactos potenciales y opciones de política publica", 2012

Resilience: what factors limited the impacts?

Drought in Central America demonstrates the importance of "meaningful inclusion" for avoiding disasters. This concept requires addressing poverty and income distribution by involving everyone, especially subsistence farmers and indigenous peoples, in planning and implementing adequate water supplies. Urban areas should also be included since many residents cannot afford bottled or trucked water. Providing and maintaining basic water and sanitation infrastructure as a public service can prevent drought disasters. The case study shows that drought has long affected Central America, with impacts worsened by neglected water infrastructure and inequitable access.

Limited data and differing definitions make it hard to compare drought impacts across sectors and countries. However, scientific understanding of drought has improved, and initiatives exist to bridge the knowledge gap between science and other sectors. But translating this knowledge into effective risk reduction is difficult due to fragmented communication and limited coordination between institutions.

Drought risk management in Central America needs a more cohesive institutional framework. This weakness limits the monitoring and enforcement of regulations. Budgetary constraints are a significant issue, but improvements can be made through better inter-institutional and local government collaboration.

Insurance penetration in the region is low, with limited options for addressing drought impacts. Existing agricultural insurance covers only a tiny portion of potential losses and is not widely affordable. No financial solutions exist for losses related to hydropower or water supply disruptions despite the potential macroeconomic impact of such events.

Disaster risk management (DRM) currently plays a minimal role in drought preparedness. While some humanitarian and sectoral support exists, DRM efforts primarily focus on emergency response rather than comprehensive risk reduction. A more comprehensive approach is needed to address knowledge gaps, strengthen regulations, and tackle the underlying factors exacerbating drought impacts.

STEP 2: Future trends

People

- Slums are becoming a more important factor in the region's urbanisation, accounting for 29 percent of all urban residents, rising to 39 percent for Guatemala.[128] These settlements are often informal and illegal. An estimated 30-66 percent of urban dwellers in Central America do not have basic services such as water or sewer systems.[129] Between 1990 and 2015, slums grew as a proportion of Latin American residences from 6 to 26 percent.[130]
- Drought conditions in the Dry Corridor magnify food and water challenges, often leaving vulnerable people with little choice but to migrate.[131]
- Central America has some of the world's highest inequalities. Gini coefficients in El Salvador, Honduras and Guatemala are 38.8, 48.2, and 48.3 respectively.[132]
- Poverty is widespread. In Guatemala, the national poverty rate is 62 percent, rising to 77 percent for rural populations. In Honduras, the national poverty rate is 60 percent, rising to 82 percent for rural populations. Indigenous populations are disproportionately affected.[133]

Planet

- Central America is one of the world's most exposed regions to climate change, the IPCC's Sixth Assessment Report (AR6) says. It is also one of the regions most affected by climate migration and displacement. By mid-century, the main climate impacts on the region will include significant heat waves,[134] increased intensity of tropical cyclones,[135] relative sea level rise, coastal flooding, erosion, ocean acidity, and aridity, drought and wildfires.[136]
- Without significant investment, urban and rural water scarcity is set to increase.

Prosperity

- CEPAL says drought will cause agricultural production to fall by as much as 22 percent by the end of this century.
- Food consumer price inflation (CPI) stands at 7.5 percent and shows few signs of decreasing. Other factors, such as currency depreciations and insecurity, suggest that CPI is likely to remain high.
- Central America is one of the world's most urbanised regions, with the second-fastest rate of urbanization.[137] Some 59 percent of the population lives in urban areas and this figure is expected to reach 70 percent within a generation.[138]

128 Maria et al., 2017
129 Fetzek, 2023
130 IPCC, 2022
131 Juárez-Lucas et al., 2024
132 World Bank, 2024(c)
133 ECLAC, 2018; ECLAC, 2019b; BCIE, 2020
134 IPCC 2022/Taylor et al., 2018
135 IPCC 2022/WGI AR6 Section 12.4.4.3, Ranasinghe et al., 2021
136 IPCC 2022/WGI AR6 Table 12.6, Ranasinghe et al., 2021
137 Maria et al., 2017
138 Fetzek, 2023

STEP 3- Forensic learning

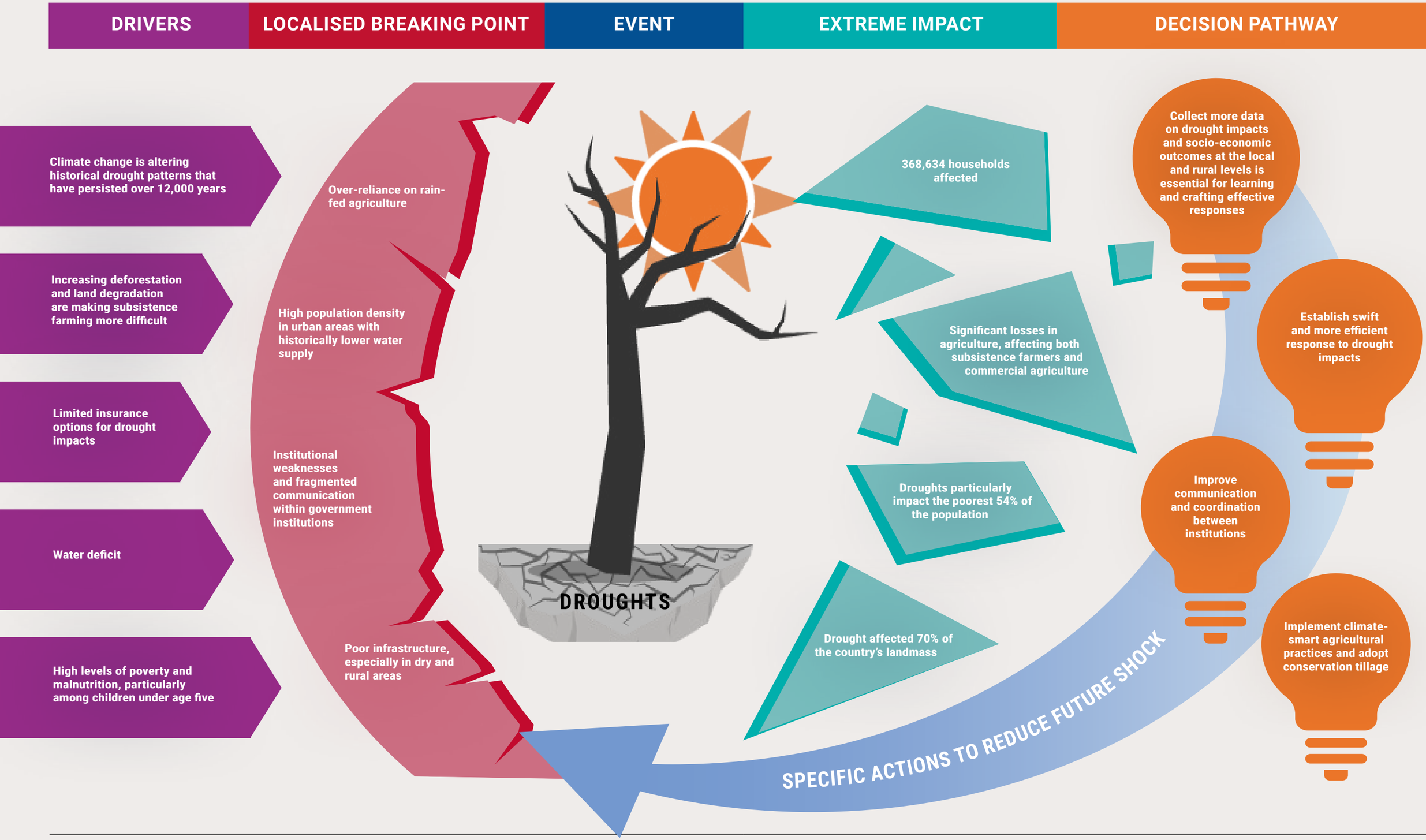
This section aims to encourage dialogue around the forensic analysis to foster improved decision making. The areas for consideration below are envisaged as an input to stimulate in-country discussion and action plan on future disaster prevention and enhanced disaster risk management

	People	Planet	Prosperity
Learning from the past	Droughts disproportionately affect the poorest 54 percent of the population. Drought is also associated with higher rates of child malnutrition and other negative health and social outcomes. Limited local data on environmental events and socio-economic data hinders effective response. There are almost no safety nets in place to protect vulnerable populations, while people continue to reside in drought exposed areas. Aging water treatment and distribution infrastructure in dry regions is often inefficient, blocking access to water, especially in rural areas.	Drought regularly affects over 70 percent of Central America's landmass. Better risk management is key to sustainable development. Drought impacts exacerbated by government institutional weaknesses and fragmented communication. Water deficits in densely populated areas, as well as poor infrastructure, also worsen drought effects. Hydro power production also falls during drought, increasing the cost of energy and driving inflation. Environmental degradation, including deforestation and water pollution, reduces water availability and exacerbates drought impacts.	Droughts cause economic losses and increase poverty. Water scarcity disrupts industrial operations and increases energy costs. Insurance penetration in the region is low. Limited coverage is offered for drought impacts, hindering economic resilience. Inter-institutional and local government collaborate to improve drought resilience.
Resilient features	Small-scale farmers and indigenous peoples often find ways to adapt despite limited resources.	Scientific understanding of droughts has improved, aiding early detection and mitigation efforts.	Canada has demonstrated an ability to adapt and recover, minimizing long-term economic disruptions. Canada has swiftly addressed infrastructure needs and diversified economic activities. This helps to mitigate the broader economic impacts of such disasters.
To inform the future	Improving infrastructure will reduce water loss and help to manage water scarcity more effectively. Use innovative approaches to capture and store any available water. Reduce consumption. Increase 'cross per drop' in agriculture. Engaging communities in water management systems can help create locally sustainable solutions.	Enhance the capacity of local water management institutions to plan, implement, and monitor water resource projects Encourage the adoption of agroforestry practices to improve soil quality and water retention.	The agriculture sector may need to further consider the use of drought-resistant seeds and small-scale production methods which use less water. Develop financial aid mechanisms to mitigate the impacts of recurring drought.

Cattle grazing on arid land in project area, watched over by young herdsman during the dry season

Source: FAO/Lou Dematteis

Central America Drought / 2023



Southern Africa Cyclone / 2023

Case Studies No 9

Preparedness for Cyclone Freddy, Quelimane, Mozambique

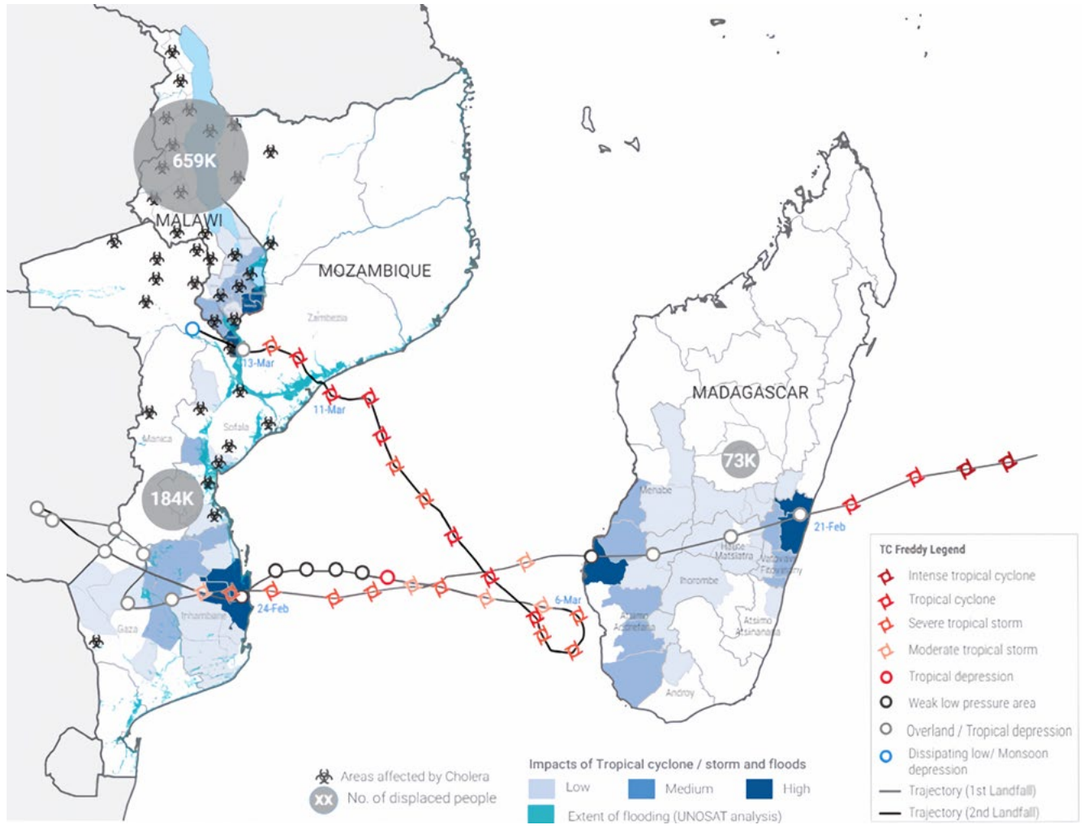
Source: SADC Humanitarian and Emergency Operations Center (SHOC), Mozambique

Step 1: Understanding the disaster DNA

What Happened?

Tropical Cyclone Freddy was an exceptionally powerful storm with a record-breaking lifespan and strength, as well as an unusual trajectory. Between February 4 and March 14, 2023, it travelled across the southern Indian Ocean from Indonesia to southern Africa, impacting Madagascar, Mozambique, southern Zambia, northeast Zimbabwe, and Malawi. Freddy generated a total accumulated cyclone energy (ACE) equivalent to an entire cyclone season in the southern Indian Ocean.

Figure 22. Cyclone Freddy lasted 36 days and traveled over 12,713 Km, reaching very intense levels storm surge to Madagascar and southeastern Africa



Source: Tropical Cyclone Freddy's impact (February - March 2023, OCHA)

The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Freddy set records for its duration and the area it covered. Lasting 38 days overall, it covered 35.5 days and 12,800 km with winds at or above 55 km/h. Meanwhile, its frequent track changes were also unusual. After crossing the southern Mozambique Channel, it circled back to hit the same areas multiple times, generating some of the heaviest rainfall ever recorded. Local reports noted significant storm surges along Madagascar's east coast and in central Mozambique.

By the time Freddy reached Madagascar's east coast, it had weakened to a tropical cyclone with winds reaching 150 km/h at sea and gusts near the centre up to 215 km/h. These areas were still recovering from two previous cyclones that had hit just weeks before.

On February 23, the storm intensified rapidly into a severe tropical storm bringing over 200 mm of rain in just 2 hours to southern Mozambique and the coast, some of the heaviest rainfall ever recorded. Freddy then slowed, reversed direction, and headed back over the southern Mozambique Channel and southern Africa. Parts of southern Mozambique experienced rainfall totals between 400 and 800 mm.

In early March, Freddy strengthened again, circled back over Madagascar, and made a second landfall over Mozambique, where it caused extensive flooding especially in Quelimane and surrounding areas. Around March 13, heavy rains intensified over central Mozambique and Malawi, with rainfall totals between 500 and 1,000 mm over 4 days. One station recorded 1078 mm. The heavy rains in Malawi led to flooding, flash floods, and landslides in hilly areas.

Exposure: Where was the damage concentrated?

Freddy's extreme storm track, strength and longevity - in an already devastating storm season - were key factors in determining its impact.

In Madagascar, many communities were still recovering from two previous cyclones when Freddy struck, exacerbating the damage. Factors such as poverty, poor housing, unplanned development, and deforestation increased these communities' vulnerability.

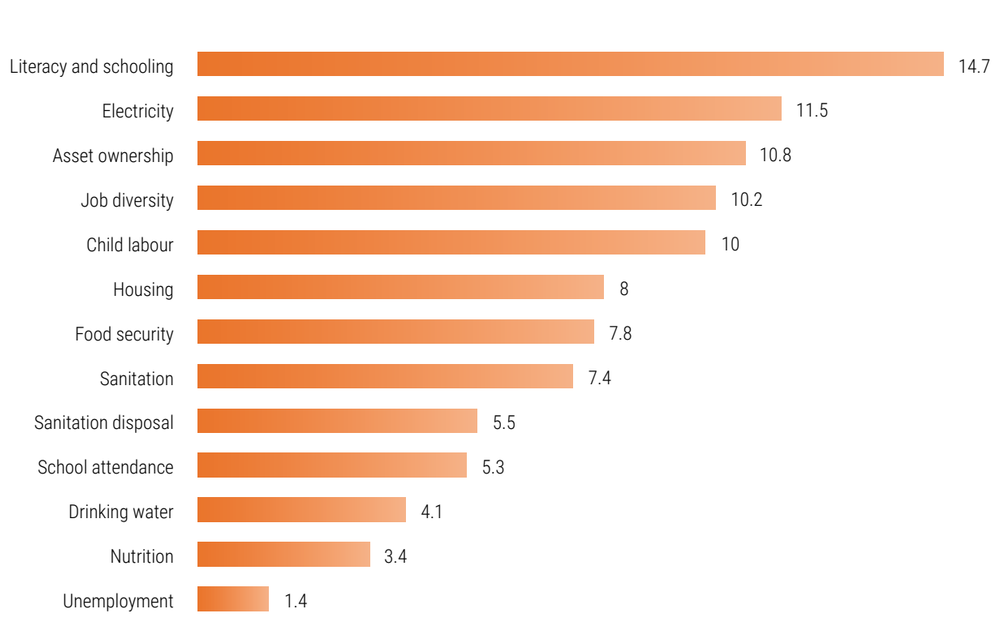
In Mozambique, excessive rainfall led to severe flooding in places with poor drainage or those below sea level, such as Quelimane. Population growth, land scarcity, rapid and unplanned urbanization and poor housing further increased exposure to the storm's impacts.

Freddy also impacted areas in Mozambique that were typically more prone to droughts and earthquakes but not widespread flooding. The storm presented a new and unfamiliar hazard for these communities, which lacked coping mechanisms and other resources.

In Malawi, deforestation and land degradation heightened the risks of flood and landslide. The southern region, with higher poverty rates, was most affected.

In all affected countries, population growth, poverty and land scarcity have driven people to settle in more hazard-prone areas, perpetuating vulnerability.

Figure 23. Lack of education, electricity, and assets traps many Malawians in poverty. However, jobs and food security were vulnerable before the cyclone and could be impacted by future disasters



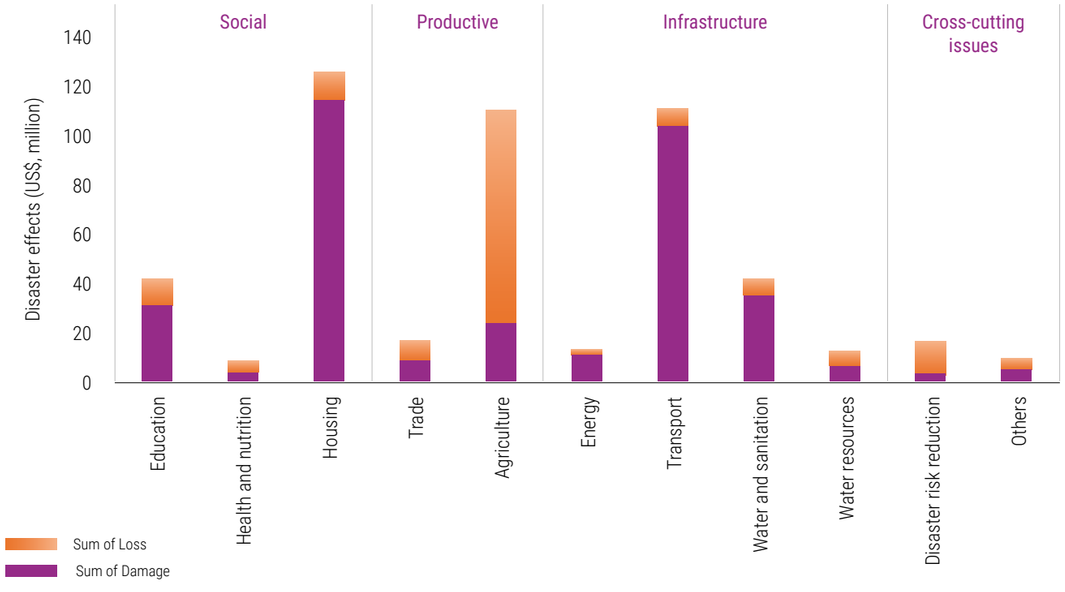
Source: National Statistical Office of Malawi and Ministry of Finance and Economic Affairs of Malawi. (2022). The Second Malawi Multidimensional Poverty Index Report.

Freddy was the second most costly and deadly system in the southwest Indian Ocean after cyclone Idai in March 2019. Economic damages were estimated at $481.5 million in Madagascar,[139] $150 million in Mozambique,[140] and $680.4 million in Malawi,[141] where about 30 percent of the affected population was displaced.

Factors like charcoal use for energy led to deforestation and ecosystem degradation, creating vulnerability to storm surge, erosion, landslides, and flooding. In Malawi's hilly areas, soil erosion had formed gullies, enabling mass debris flows associated with landslides. Linked to poverty, poor construction further increased vulnerability in all affected areas.

Over-reliance on natural resources caused soil erosion and uncontrolled runoff, leading to rapid river level rises and severe floods. Settlements in disaster-prone areas are often a result of generational ties, lack of infrastructure in safer areas and lack of information on past disasters.

Figure 24. While the cyclone's primary damage was to housing and transportation infrastructure, the most significant economic losses were felt by farmers, who lost most of their crops



Source: National Statistical Office of Malawi and Ministry of Finance and Economic Affairs of Malawi. (2022). The Second Malawi Multidimensional Poverty Index Report.

139 African Risk Capacity Group, 2023(b)
140 World Bank, 2023
141 PreventionWeb, 2023

Vulnerability: Who was affected and why?

Cyclone Freddy was an unprecedented event that challenged traditional preparedness systems in multiple ways. It caused about 20 deaths in Madagascar, 200 in Mozambique and more than 670 in Malawi, the hardest-hit country.

In Malawi, 659,278 people were reportedly displaced, representing about 30 percent of the total affected population of 2,267,458, according to the Malawi Department of Disaster Management. The affected areas were not accessible by land, so medical and housing assistance was provided via helicopters with help from Tanzania and Zambia

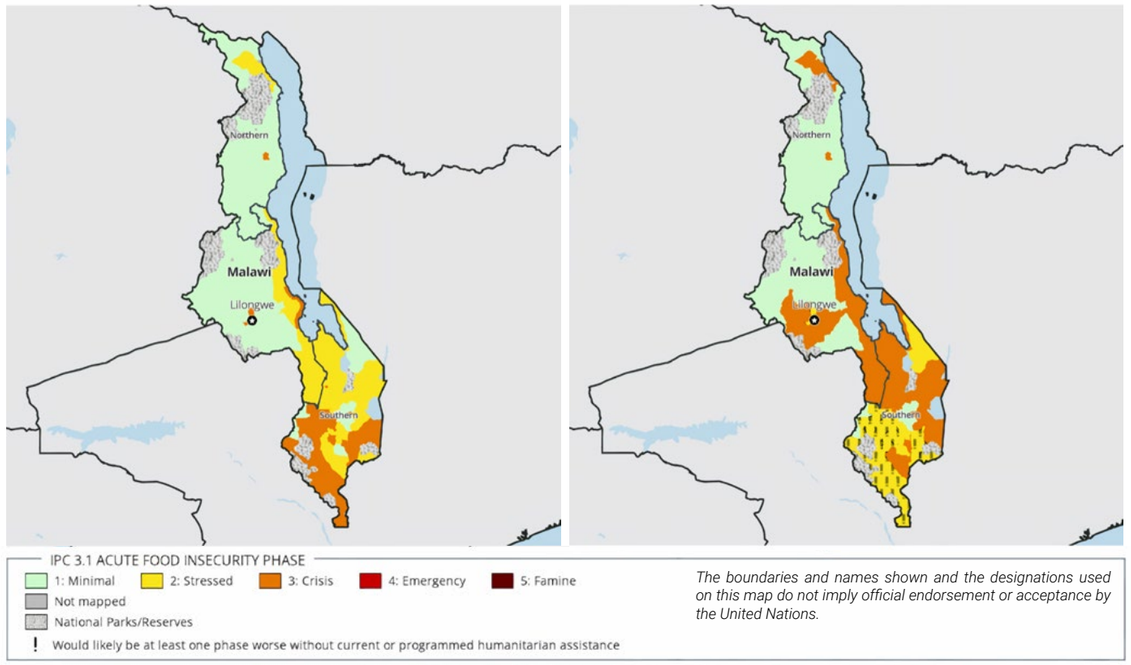
Population growth, rapid urbanization, and poverty have driven expansion into hazard-prone areas, often resulting in informal settlements. Safer areas were occupied first, but poor and marginalized individuals could not afford land or rent in these areas, leading them to settle in unsafe locations. Poverty also contributed to poor construction quality.

In many places, land-use planning norms, building codes and safety regulations were not adequately applied or enforced. Very few people had insurance against loss and damage from extreme events. While other types of insurance are available in Malawi, Mozambique, and Madagascar, including parametric crop insurance and traditional property insurance, they are not mandatory and remain unaffordable for most of the population.

Freddy's impact was not evenly distributed. Poverty emerged as a key vulnerability factor, with low-income communities in high-risk areas being hit the hardest. Chronic social issues like unemployment and poor health further exacerbated vulnerability by reducing coping capacity and hindering social support networks.

Malawi's updated Nationally Determined Contribution (NDC) estimates that climate change causes annual economic losses equivalent to at least 5 percent of GDP.[142]

Figure 25. Six months after Tropical Cyclone Freddy hit southern Africa, districts in southern Malawi were expected to face crisis conditions, driven by significant reductions in food and cash crop production, reduced access to income, and higher prices of food. Most households in the south had not yet recovered from the storm's impacts



Source: FEWS NET. (2024). Crisis (IPC Phase 3) Persists in south due to below-average crop production

142 Republic of Malawi, 2021

Resilience: what factors limited the impacts?

Cyclone Freddy in stoutheast Africa in 2023 demonstrates that "the right mindset" can help avoid disasters. Mozambique showed this mindset through its legislative, policy, and planning framework for tackling disasters, saving many lives through timely warnings, evacuations to safe locations, and readiness at evacuation centres. However, deforestation, poverty, and poor living conditions left many people vulnerable, resulting in around 200 cyclone deaths.

In contrast, Malawi had not made as much progress in adopting the right mindset. Significant deforestation, worse poverty, widespread informal settlements, and a lack of planning and preparedness, led to around 1,200 deaths. The storm also struck during the country's worst-known cholera outbreak.

All impacted countries have legal frameworks and disaster risk management strategies, but their effectiveness needs further investigation. Disaster risk reduction must be integrated into broader policies like land-use planning and environmental management.

Madagascar has a law on National Risk and Disaster Management Policy (Law No 2015-031)[143] as well as a 2016-2030 national strategy for risk and disaster management,[144] which aim to build resilience against shocks. The IFRC and UNDP conducted a case study to assess the impact of these laws and regulations on disaster risk reduction in the country.[145]

Mozambique enacted Law 10/2020[146] on Disaster Risk Management and Reduction, establishing a legal framework for disaster risk governance. The National Disaster Management Institute coordinates disaster risk management and reduction. A multi-sectoral Disaster Risk Reduction Plan with a 2030 horizon demonstrates government commitment to reducing disaster risk and promoting resilience.

Malawi has draft building regulations and a 2016 Physical Planning Act,[147] but strict codes or laws are not enforced outside cities. Malawi also has a national disaster risk management policy, although its effectiveness needs assessment.

All three countries are members of the African Risk Capacity (ARC)[148] insurance scheme, which provides parametric insurance for extreme climate events. Madagascar and Mozambique received ARC payouts of $1.5 million and $4.4 million respectively.

All three countries have contingency plans based on seasonal forecasts, which consider disaster risks in vulnerable sectors such as agriculture, health, and water. Disaster risk is considered in specific projects in priority areas such as education, health, and infrastructure development. However, efforts to integrate disaster risk management into development planning and climate change adaptation are ongoing in Madagascar, Malawi, and Mozambique.[149] [150] [151]

Risk knowledge remains a major challenge, with limited systematic assessment, documentation, and public awareness. Integrated risk analysis is essential due to the increasing risk of cascading events. Limited knowledge and awareness reduce the ability of at-risk populations to adopt appropriate behaviours for risk reduction.

Malawi lacked enforcement of city building bylaws[152] and guidelines on safer house construction.[153] This resulted in settlements in high-risk areas such as mountain slopes and stream banks.

Environmental degradation and ecosystem service depletion are concerns in all three countries. Laws relating to land use, deforestation, and ecosystem conservation need better enforcement.

143 Republic of Mozambique, 2024
144 Government of Madagascar, 2012
145 IFRC, 2014
146 Government of Mozambique, 2020
147 Government of Malawi, 2016
148 African Risk Capacity Group, 2024
149 Global Facility for Disaster Reduction and Recovery (GFDRR), 2024 (a)
150 Trogrlić et al., 2024
151 Global Facility for Disaster Reduction and Recovery (GFDRR), 2024 (b)
152 Blantyre City Council, "Blantyre City Council By-Laws"
153 Ministry of Lands, Housing and Urban Development (Malawi), "Safer House Construction Guidelines"

Step 2: Future Trends

People

- Where infrastructure and transport networks are poor, evacuations become more difficult and costly, even requiring helicopter support.
- Informal settlements in these areas will likely grow as the cost and logistical challenges of relocating to safer areas remain prohibitive for most residents.
- The African Risk Capacity (ARC) Group in 2023 launched a new parametric insurance mechanism to help African countries cope with the devastating effects of flooding. This insurance is already available for Madagascar, Malawi and Mozambique.[154]
- Over the past two decades, southern Africa has seen their food import bills increase sharply from $35 billion in 2019 to $43 billion in 2022. According to African Development Bank projects that food imports into southern Africa will reach $90 billion by 2025.[155]

Planet

- With median temperatures increases of 1.6°C and 2.2°C by mid-century,[156] more intense and volatile cyclones are expected.[157]
- Like Freddy, these cyclones may become more intense, and long-lived, with novel trajectories striking previously unaffected areas.
- While drying is a general projection for the region, IPCC climate models also indicate likely subregional increases in intense rainfall events in eastern southern Africa, including the eastern escarpment regions of South Africa and Mozambique. These changes reflect longer dry spells interspersed with more intense downpours.[158]

Prosperity

- Without urgent risk reduction measures, more intense and volatile storms will continue to undermine investments in infrastructure and sustainable development.
- While the percentage of people employed in agriculture is decreasing in southern Africa,[159] the sector still employs more than 70 percent of the region's poor population.[160]
- Climate change has already caused significant declines in agricultural production in southern Africa. Due to global warming, cereal production in the region has significantly declined over the past decade and is projected to further decline by more than 20 percent by 2030.[161]
- Globally tropical cyclones are among the most harmful extreme weather events, affecting an average 20.4 million people each year and causing mean direct annual economic losses of $51.5 billion over the last decade. The growing empirical evidence suggests that the impacts of tropical cyclones can reduce economic growth in affected countries for more than a decade.[162]

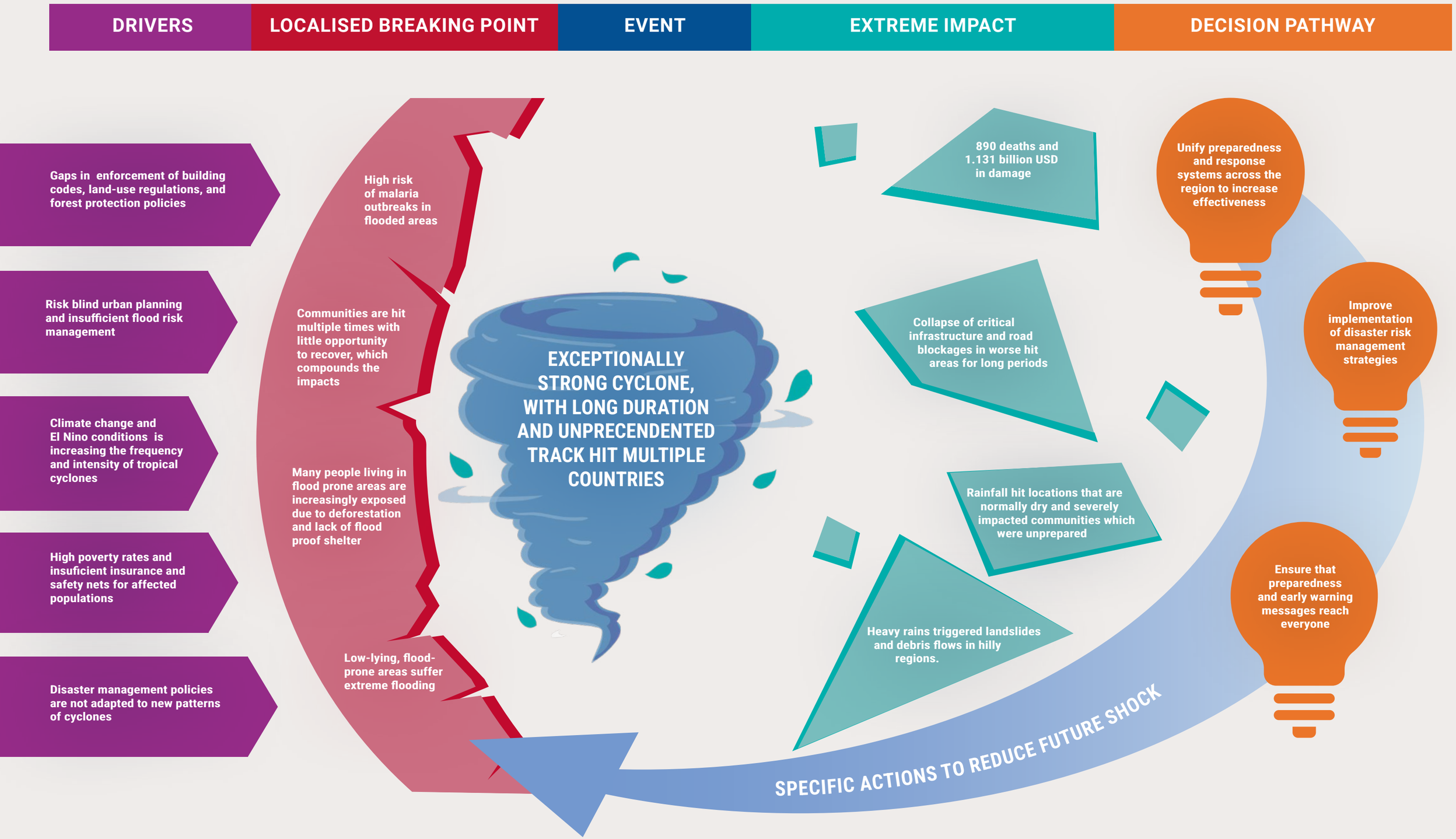
154 African Risk Capacity, 2023 (a)
155 AfricanNews, 2017
156 IPCC, 2018
157 Collins, 2019
158 Engelbrecht, 2024
159 Yeboah, Kwame, and Jayne, 2018
160 Swiss Agency for Development and Cooperation (2013)
161 FAO, 2022
162 Krichene et al., 2023

Step 3: Forensic learning

This section aims to encourage dialogue around the forensic analysis to foster improved decision making. The areas for consideration below are envisaged as an input to stimulate in-country discussion and action plan on future disaster prevention and enhanced disaster risk management

	People	Planet	Prosperity
Learning from the past	The cyclone hit locations, which were previously not considered to be at risk. They were unprepared. People often refuse to re-locate from hazard-prone settlements to safer areas because they cannot afford to do so. Or the new areas are far from jobs.	As events become more intense and volatile, southern Africa and individual countries will need to upgrade mechanisms for risk prevention and management. Deforestation and unsustainable land management exacerbate impacts such as floods and landslides. The cyclone occurred at a time when Malawi was already experiencing a major cholera outbreak. Preparations need to be multi-hazard and flexible.	Agriculture employs over 70 percent of people in the impacted regions. Recovery of this sector is especially important. Governments did receive insurance payouts through the CRIF. However, few households or small businesses had coverage. Roads and infrastructure were often unable to withstand the extreme conditions. Possible factors included insufficient maintenance or design. The cyclone destroyed infrastructure in a region where coverage was already insufficient.
Resilient features	International cooperation, especially from neighbouring countries helped considerably with evacuation and relief. Community disaster risk management activities reduced the number of fatalities compared with previous events. Informal social support systems were key to provide immediate assistance and support.	Early warning systems effectively identified the hazard risks. However, not all communities were able to receive and act on the warnings. All three countries have legal frameworks for environmental protection.	Coverage was limited, but parametric insurance mechanisms were able to release some funds.
To inform the future	Increase social safety nets for the poorest households to reduce the humanitarian damage and speed recovery. Increase the availability of safe housing. Incentivise livelihood approaches to restore ecosystems. These protect against cyclone and flood impacts. Strengthen regional cooperation for disaster risk management.	Strengthen the laws, codes and compliance mechanisms for safe housing in informal settlements. Enhance land-use planning and restoration of ecosystems. Enforce environmental protection laws. Encourage reforestation in high-risk areas to reduce flood and landslide exposure.	Invest in basic infrastructure Diversify the economy. Assess availability and feasibility of existing social safety nets. Improve access to risk sharing and transfer mechanisms for both government and communities. Pool regional risk. Implement regional commitments to build resilience.

Southern Africa Cyclone / 2023



Lebanon floods / 2024[163]

Case Studies No 10

Damaged crops in the aftermath of the flood near Ostouane river

Source: National Council of Scientific Research

Step 1: Understanding the disaster DNA

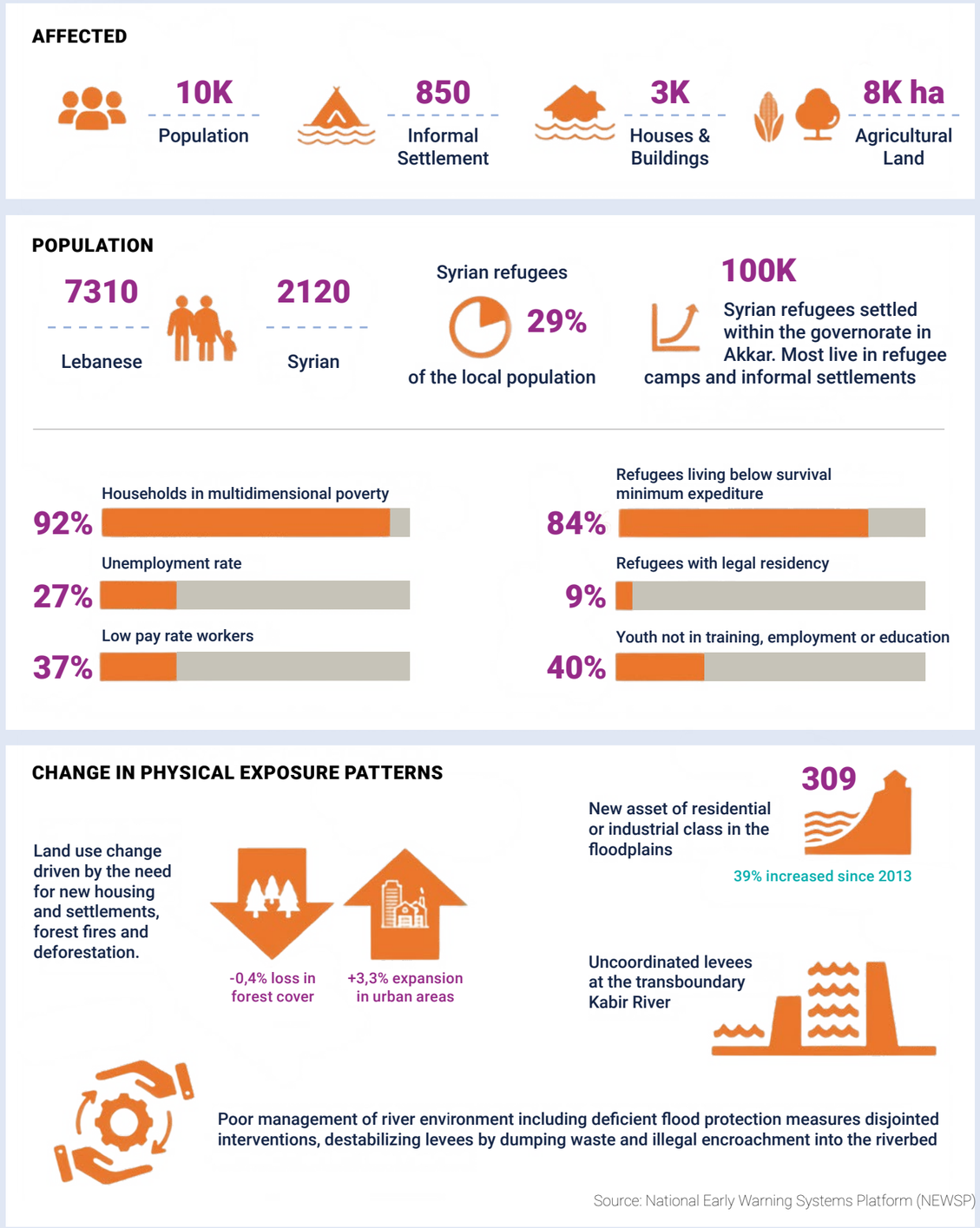
What happened?

After seven days of heavy rain in January 2024, two rivers in Northern Lebanon flooded simultaneously, covering a large area with mud and debris. Coastal roads were submerged, blocking food aid distribution and preventing some people from getting to work. Villages were isolated and cut off from essential services for several days.

Early warning prevented widespread loss of life, but the destruction was severe, flooding 3,000 houses and 850 informal settlements, affecting a total of 10,000 people, including many refugees from Syria. It was the region's largest flood in more than 20 years.

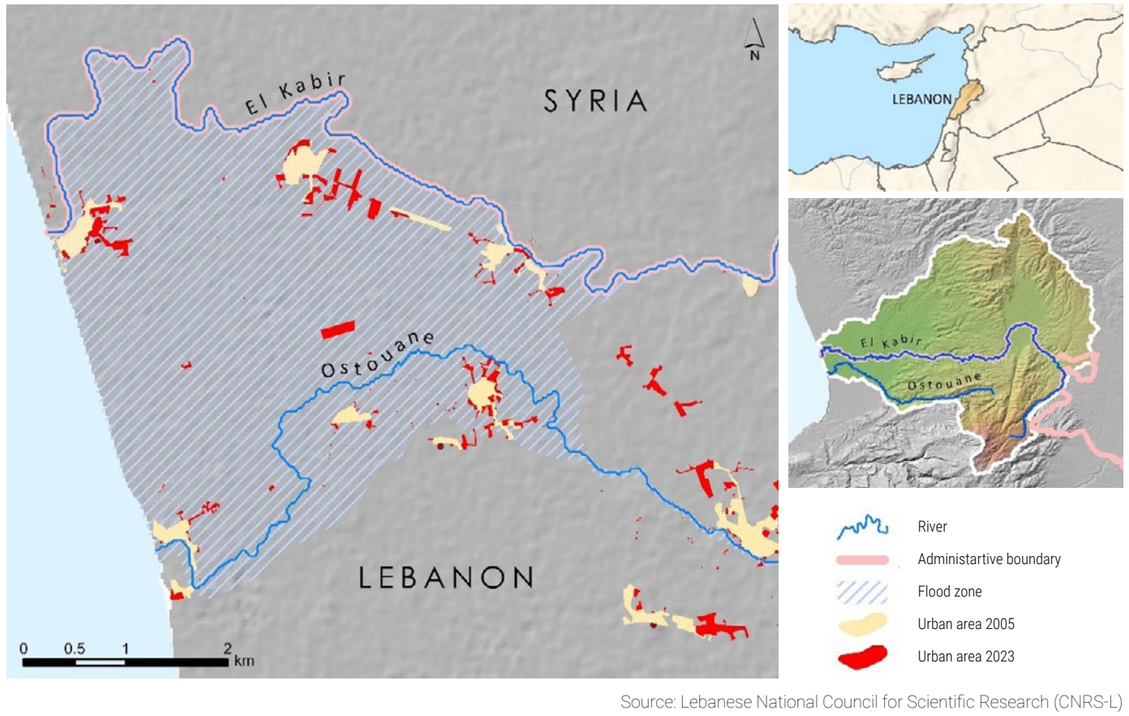
163 Abdallah, 2024

Figure 26. Floods in numbers, Lebanon 2024



Source: National Early Warning Systems Platform (NEWSP)

Figure 27. **Map shows affected areas in January 2024 after two rivers in northern Lebanon – the El Kabir River and the Ostouane River - flooded simultaneously**



Source: Lebanese National Council for Scientific Research (CNRS-L)

The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Exposure: Where was damage concentrated?

The flooding affected the districts of Tripoli and Akkar, both in northern Lebanon. The El Kabir River, which marks the Syria-Lebanon border, flooded south into Lebanon, while the Ostouane River also overflowed. When the two rivers breached their banks in several places, the floodwaters devastated vast areas across Lebanon's agricultural Akkar plain. Most households in the flood zone suffered damage.

Despite the risks of flooding, the size of urban settlements had more than doubled in the past two decades, partly due to the influx of refugees from Syria. This urban growth highlighted the complex relationship between population dynamics, lack of policies, and extreme poverty.

Roads and highways turned into rivers, trapping many cars and small trucks. The flooding also impacted local businesses and services. In Akkar, hundreds of Lebanese and Syrian families were evacuated to temporary shelters such as schools and mosques, while some residents had to be rescued by boat.

Rural areas were also heavily hit. More than 70 percent of people in the region rely on agriculture and livestock for their livelihoods. The floods covered some 8,000 hectares of agricultural land, destroying crops, as well as agricultural equipment and infrastructure. The loss of these assets impacted employment and income, especially for the poorest households.

The floods also brought new dangers into the flood zones, lifting mines out of Syria and scattering them across the riverbeds.

Vulnerability: Who was affected and why?

The floods underscored how poverty exacerbates risk. More than 90 percent of the area's population was living in poverty, while Lebanon was also suffering from hyperinflation and high unemployment at the time. Most families had few financial reserves and almost none had flood insurance.

Poorer communities were less able to respond, mitigate, and recover. They had less options for evacuating to higher ground or safer areas and less access to transport. Their housing was of poorer quality and less resilient. The most affected individuals were often unemployed, had limited access to basic services, and were lacking proper healthcare.

This pattern is not uncommon. World Bank analysis of major disasters finds that the poor lose two to three times the relative amount of their relative wealth because their assets and livelihoods are so vulnerable.[164] These asset losses often translate into income losses too.[165]

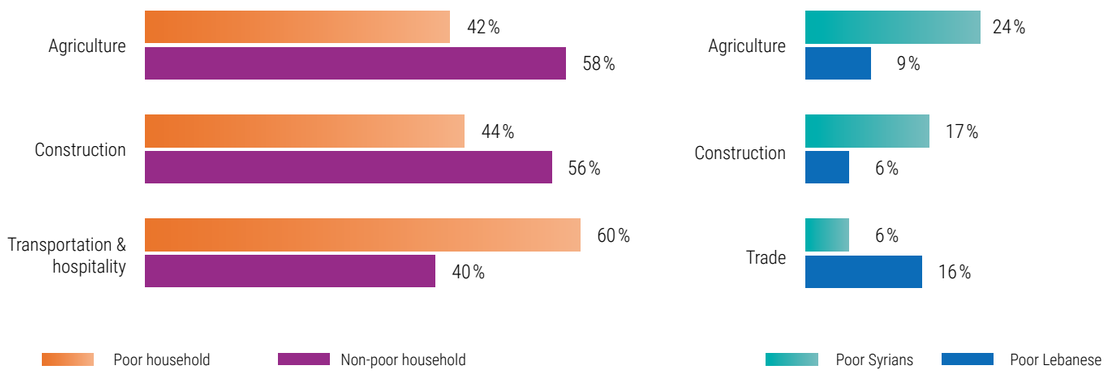
Of all the people affected, some 2,000 were registered refugees. Even before the floods they had been unable to afford their basic family needs and were heavily reliant on humanitarian aid. They were the worst affected.

Accounting for 29 percent of the flooded populations, most refugees were living in tent housing, often in informal refugee camps on the outskirts of villages. Their tents offered little protection against the flooding and their informal settlements became uninhabitable. These settlements had not been planned in any coherent way, but the refugees benefitted from lower costs and easy access to both agricultural land and to the rivers. As a result, their settlements tended to expand towards the rivers.

Besides being very vulnerable to flooding, the Syrian refugees also accelerated urban growth and thus the impacts of flooding. Many settlements in the area dumped their waste into the river and developed informal roads across the riverbed too, disrupting the morphology and flow of the rivers. Issues related to water and waste management, land encroachment, informal draining systems and road networks complicated the situation.

Meanwhile, flood management practices were uncoordinated and inadequate. Local farmers did little to protect themselves from flood risks and the construction of a large embankment on the Syrian side of the El Kabir River in 2011 added further imbalance to the levee system.

Figure 28. **A significant portion of workers from poor households are employed in low-skilled sectors, particularly agriculture. Syrian households constitute a major share of the workforce in these sectors.**



Source: World Bank (2024), Lebanon poverty and equity assessment

164 Hallegatte, 2016
165 Barrett, Reardon, and Webb, 2001

Resilience: what factors limited the impacts?

This case study highlights the lack of enforcement in various aspects of governance, including building codes and regulations intended to ensure the resilience of critical infrastructure and buildings against flooding. As emphasized, the poorest are always the most significantly impacted. The threat is particularly acute in places like Lebanon, which hosts many migrants and refugees who are often forced to stay in high-risk areas due to the scarcity of available land. Their livelihoods, if they have any, are vulnerable to extreme weather events.

Governments can and should choose to invest in resilience, and these floods demonstrated the need to do so. Building resilience involves the recognition of hazards such as flooding and taking the appropriate actions, including the construction of flood protection infrastructure, planning for potential relocation of communities in flood zones, and building awareness among local populations. Governments should also focus on implementation at the local level, working with communities, business, and non-governmental organisations.

In Lebanon, disaster risk reduction had been included in national strategies and laws, but these contained ambiguities and were often imprecise. Enforcement remains an issue.

Under the existing building code, for example, the government can impose technical requirements for construction in flood-prone areas and even deny building permits completely. However, the laws do not specify the risk criteria or technical specifications necessary.

Similarly, the Lebanese water law emphasizes the need to protect and preserve river environments and ecosystems, prohibiting development within river buffer zones. However, it fails to set clear physical limits, legal policies, and enforcement strategies appropriate to the level of existing risk.

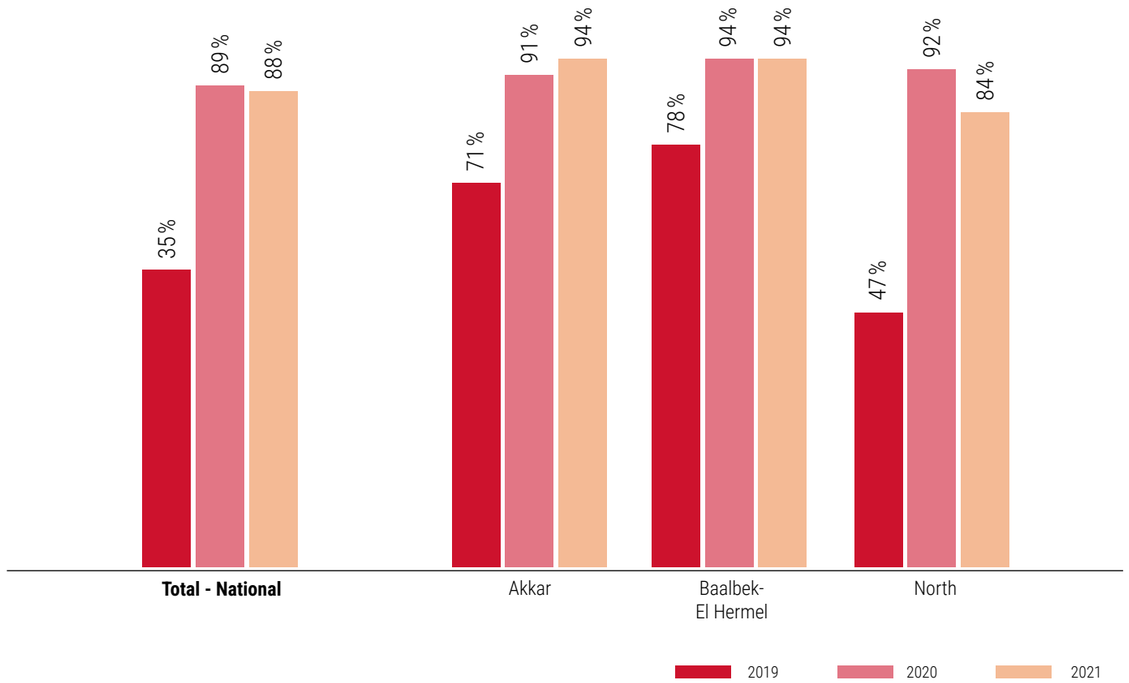
Lebanon's ongoing economic crisis further undermined the government's ability to enforce these laws. Reflecting this ambiguity, insurance policies often failed to cover flood risks.

One significant step forward for Lebanon was the development of the National Early Warning System Platform (NEWSP). In collaboration with the National Council for Scientific Research in Lebanon, NEWSP uses satellite imagery and digital modelling to actively research and predict natural hazards. It also assesses risks to critical infrastructure such as schools, hospitals, and factories. Its existence explains why so few lives were lost in the flooding.

Flooded greenhouses Ostouane river, January 2022

Source: National Council of Scientific Research

Figure 29. Nearly all households in high Syrian migrant regions (Akkar, Baalbek-El Hermel, and North governorates) are below the Survival and Minimum Expenditure Basket (SMEB): refugees' expenditures are two-thirds of the SMEB, with significant differences across shelter types and food security levels



Source: UNHCR, UNICEF, WFP, Vulnerability Assessment of Syrian Refugees in Lebanon, 2021

Step 2: Future Trends:

This section looks at key root causes or emerging issues identified above and provides a snapshot of potential 'business and usual' trends where action now could prevent or reduce disasters in the future.

People

- Over the past decade, Lebanon – with a population of 5.2 million - has endured multiple crises, including political instability, the fast changing financial and economic situation, as compounded by the COVID-19 outbreak, the Beirut Port explosions, and the impact of the Syria crisis.[166] [167]
- In 2021, emigration numbers increased due to the multiple crises in the country. While this increased GDP through remittances which reached $7.3 billion in 2016, it also resulted in a brain drain of highly skilled Lebanese people. In 2018, literacy rates were 95.1 percent for adults and 99.8 percent for young people. By comparison, some 40 percent of Syrian youth in Lebanon were uneducated.[168]
- Some 1.5 million Syrian refugees are living in Lebanon, with only 20 percent of those above the age of 15 holding legal residency. A 2023 UN assessment found that 84 percent of Syrian refugee families are living in extreme poverty, unable to afford the survival minimum expenditure basket (SMEB). Shelter conditions for refugees remain largely substandard.[169]
- By mid-April 2024, the conflict in southern Lebanon and the Gaza had forcibly displaced around 93,000 Lebanese and secondarily displaced thousands of refugees. The development highlights political instability as a major driver of risk.[170]

Planet

- Lebanon's changing rainfall patterns, which have been attributed to increasing temperatures, affect the frequency of intense rainfall events and alter catchments and drainage basins. Increased winter rainfall is leading to destructive flooding.[171] [172]
- Urbanization in Lebanon remains uneven and incoherent despite a slowdown due to the economic downturn. Urban design guidelines have yet to be updated so that buildings adapt to their surroundings and environment. Infrastructure development in areas like water, sanitation, and transportation still cannot keep pace with the needs of the urban population.[173]
- If the 29 percent of openly dumped waste continues to go untreated,[174] it could exacerbate future flooding events, particularly given the overflowing waste from Lebanon's 1.5 million informal settlements.

Prosperity

- In the space of a decade, poverty in Lebanon more than tripled to reach 44 percent of the total population by 2022. In Akkar, where most residents worked in the agriculture and construction sectors, the poverty rate reached 70 percent. Looking ahead, social safety nets will continue to play a critical role in helping households to meet their basic needs.[175]
- Lebanon's severe and multifaceted crisis has seen Lebanon's economy contract by about 40 percent, with inflation in triple digits. Uncertainty has been very high and the outlook hinges on the authorities' willingness to implement overdue reforms.[176]
- In the agricultural sector, the combined effects of climate change are expected to reduce the yield of irrigated crops by 0.3 to 8.7 percent and rainfed crops by 3.5 to 7.5 percent.[177] In many parts of Lebanon, livelihood diversity is minimal, and communities rely heavily on agriculture, which makes them highly vulnerable to such crop yield losses.[178]

166 BBC News, 2023
167 UNDP, 2021
168 European Training Foundation. 2022
169 UNHCR, "*Lebanon Operational Data Portal*"
170 Ibid.
171 UNDP, 2021
172 World Bank, 2024(a)

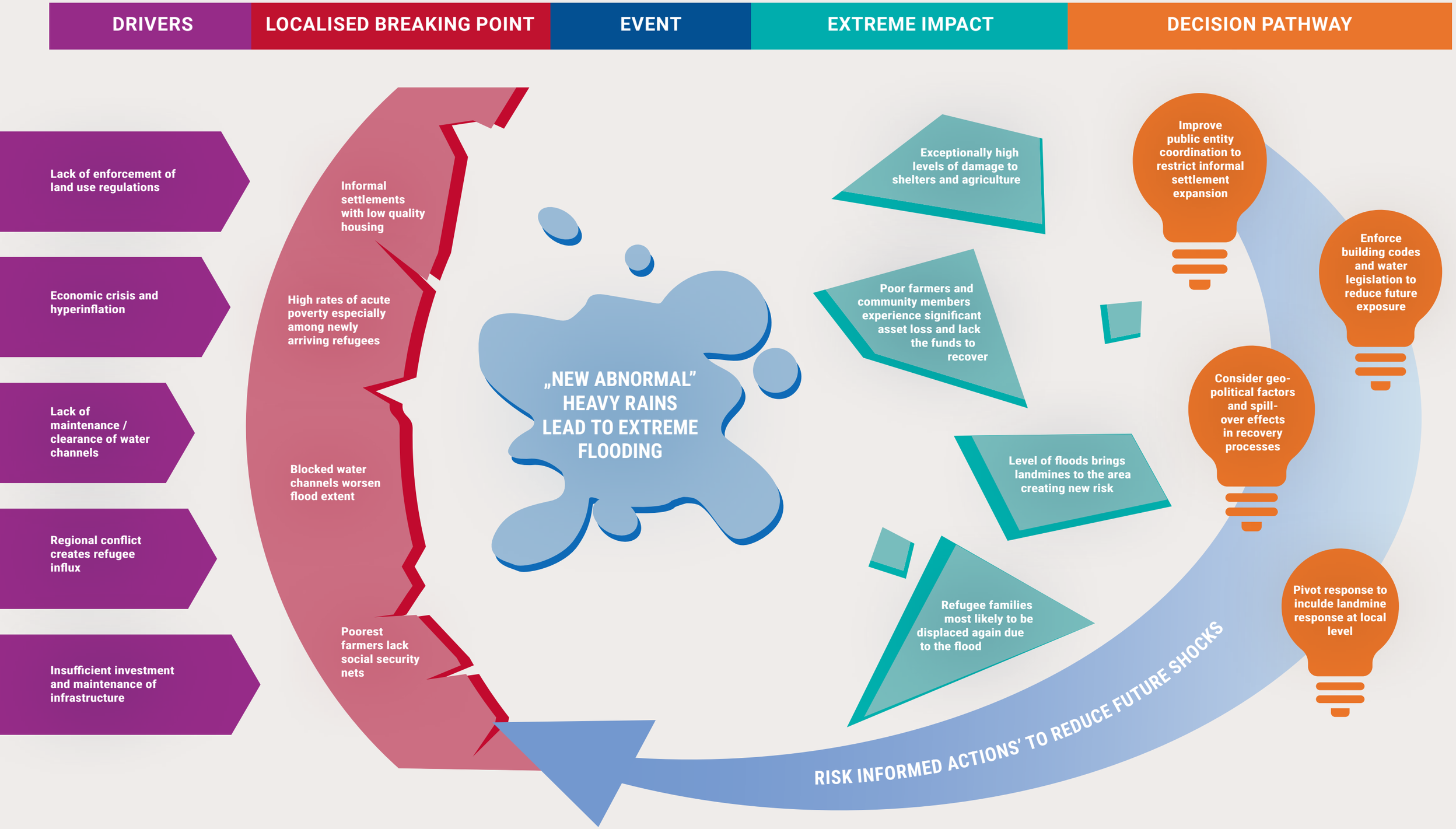
173 UNDP, 2021
174 Ibid.
175 World Bank, 2024(b)
176 International Monetary Fund (IMF), 2023
177 World Bank Group, 2024
178 Issam Fares Institute for Public Policy and International Affairs, 2022

Step 3: Forensic Learning:

This section aims to encourage dialogue around the forensic analysis to foster improved decision making. The areas for consideration below are envisaged as an input to stimulate in-country discussion and action plan on future disaster prevention and enhanced disaster risk management.

	People	Planet	Prosperity
Learning from the past	Unsafe housing was the most important indicator of acute impact and slow recovery. Refugees were almost universally living in housing that was unsafe. The lack of data disaggregated by sex and age hampers a better understanding of specific needs. Conflict hinders investment in disaster risk reduction. It slows sustainable development throughout the region.	Land use plans and legislation exist but implementation has been uneven. This increases disaster risk. By blocking rivers and waterways, waste increases flooding risk. Informal settlements used riverbeds as roads, disrupting river morphology. Flood waters brought UXO and landmines, a new danger.	The floods destroyed agricultural production, a primary source of income in the affected areas. Refugees were already reliant on humanitarian aid, but floods severely disrupted aid flows, and reduced many options for employment. Wealthier farmers had insurance. Or they were able to drain their land and restore production. The poorest farmers faced greater recovery challenges.
Resilient features	Early warning systems operated well, enabling evacuations and preventing fatalities. Social safety nets helped refugees after the floods.	Building codes and water laws aim to protect river ecosystems and create buffer zones. But enforcement was limited.	Disaster risk reduction was part of national strategies. The government aimed to protect economic activities and reduce the vulnerability of key areas to flooding. Farmers took preventive action to protect their livelihoods. They drained their flooded fields, using equipment and trenches, for example.
To inform the future	Enforce strict building codes and integrate urban planning to reduce the exposure of housing to floods. Reinforcing social safety nets for vulnerable populations, including refugees, to reduce humanitarian needs and accelerate recovery.	Restore and maintain rivers to help prevent future flooding. Develop and enforce stricter waste management policies to prevent river clogging. Integrate mine clearance and UXO management into environmental protection and disaster preparedness.	Construct flood-resistant infrastructure, including reinforced levees, drainage systems, and roads that can withstand flood conditions. Assess existing flood-resistant infrastructure to understand why failures occurred. Encourage economic diversification in flood-prone areas, reducing dependency on agriculture. Support alternative livelihoods in less vulnerable industries.

Lebanon floods / 2024



The Disasters Avoided Model

The case studies have looked at how disasters could have been avoided, or how impacts could have been lessened by taking action to build effective resilience. The Disasters Avoided Model looks at what measures have yielded positive results and what more can be done to build resilience and avoid future disasters. The Disasters Avoided Model summarizes these measures with six points outlined in the graphic below. Further information about the Disasters Avoided approach is available on https://disastersavoided.com.

Each case study includes positive elements where the disasters have been avoided or reduced. Preparedness actions build resilience, and, in many cases, these positive elements align with the disasters avoided model, which includes six key points as below:

1. The right mindset – This includes the understanding that disasters do not come from nature (there are no "natural disasters"), they come from the choices we make to live and to build in harm's way.

2. The right investment – When investments are made wisely and at the right time, then they demonstrate the value of preventive measures to avoid disasters. The right mindset ensures that resources are allocated wisely.

3. Good governance – Rooted in political and economic commitment, good governance is essential to manage these investments effectively and to deliver tangible, social, environmental, and economic benefits.

4. Good data – Informed decision-making depends on reliable data, gathered through various means, including satellite observations, AI, and on-the-ground monitoring. This data is vital to create a society that can co-exist with nature's forces.

5. Meaningful inclusion – Including all stakeholders is vital to build a society that is resilient to natural forces, especially when supported by good data, good governance, and planning.

6. Meaningful targets – Targets can connect to initiatives like the Sendai Framework, the Sustainable Development Goals (SDGs), climate change efforts, the New Urban Agenda, and the Humanitarian Agenda. They must be realistic and achievable.

An emerging model:

As we work on our case studies of disasters being avoided, we are seeing some patterns and trends which are contributing towards us starting to develop an emerging model for avoiding disasters.

This model is a "work in progress". It does not seek to cover all aspects of disaster risk reduction and management; instead, its purpose is to highlight key points that we see arising in the actions people are taking to avoid disasters in different parts of the world. There is no "right or wrong" answer to how we approach the goal to avoid disasters, and context is always important. What we are seeking to distil are some common threads that we see, which we hope are of use.

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Part 6: Conclusions

Tropical Cyclone Idai, one of the worst tropical cyclones on record to affect Africa, aftermath in Mozambique

Source: Shutterstock

As noted earlier, this report does not explore whether hazard events are becoming more frequent and extreme, because we know that a changing climate will make it so. Instead, this report seeks to limit the damage from such events by applying a "disaster forensics" approach to ten case studies and unpacking the lessons to be learned. The GAR2024 analyses key elements of hazard, vulnerability, and exposure of people and governance systems, showing how they have contributed to major recent disasters and to risk reduction. It shows how risk reduction can limit the impacts of disaster, and even prevent some disasters from occurring in the first place.

In today's complex risk landscape, the past is no longer a reliable guide to the future. However, there are important lessons in addressing different components of disaster risk, which may still be useful… We need to understand the mechanics of past and present risks, as well as the ways in which hazards expose existing vulnerability through the interactions of institutions, economics and ecosystems. This is how we identify the technical and practical choices available to us, the available investments that will make our systems more resilient.

Disasters focus attention, highlighting in one single event the systemic interactions between a range of physical, socio-economic, and institutional factors which together contribute to systemic risk.[179] Looking at the multiple lines of evidence and narrative, forensic analysis simplifies the task of understanding, analyzing, and addressing these factors. It thus makes systemic risk more manageable. The analysis will likely be transdisciplinary, not reliant on academic disciplines alone. Instead, the insights will derive from a variety of public, private, and civil society partners in a range of sectors, including spatial planning and transport, as well as disaster management. Governmental authorities, communities, and citizens will also be involved.

Indeed, forensic studies clearly show the need for multi-disciplinary governance, especially when global or regional risks manifest at local level.[180] They provide a comprehensive evidence base for territorial governance, which is broader than individual sectors, encompassing processes such as land-use planning, natural resource management, and the planning of resilient infrastructure. Forensic analysis identifies opportunities to align governance across multiple jurisdictions and interests. The imperative is to understand and act on the interdependent and multidimensional risk drivers that play out across geographic and temporal scales. To that end, we highlight the following key recommendations from this report:

- Take action to reduce vulnerability and exposure to hazards in advance. This helps by acting as a shock-absorber, buffering the impact of more intense hazard events or the cumulative impacts of smaller events.

- Use forensic analysis to understand how disasters impact across people, territories and prosperity, drawing on this knowledge to guide risk reduction actions, especially in locations where natural infrastructure services are present but strained by more intense and cascading risks. Couple vulnerability reduction with nature-based solutions such as protecting wetlands to absorb flood waters or preserving coastal forests to buffer against storms and reduce erosion.

- Invest in information quality and standardization, broaden data sets to include social and environmental factors, and apply effective methodologies in sectoral and land use planning. These are all essential components for reducing disaster risk. The quality of information on risk and disasters has improved remarkably in the last three decades, but much remains to be done.

- Build alliances and partnerships across sectors, for example by training individuals in alliances and civil society, including non-governmental organizations and other organized groups or networks. Civil society brings together professionals from diverse sectors, communities, indigenous groups, women, migrants, people living with disabilities and other vulnerable groups. It can foster proactive and prospective risk management, as well as vital post- disaster activities.

- Identify prospective risk drivers, by analyzing major disasters. Use insights gained to strengthen early warning systems, focusing more on the likely failures of system key nodes and buffers in order to protect against potential disasters.

- Utilise continuous, deliberative and accelerated learning cycles, which are central to effective systemic risk reduction. This requires collaboration with local experts and communities, listening to them and working with them. Put systems in place that measure and learn from disasters so that lessons learned can be proactively applied. Change direction as new knowledge and partners emerge.

Resilience will be vital for future generations to sustain their development and well-being. A vital concept for engineering, economies, ecosystems, social development and well-being, it needs to be internalized. Just as importantly, perhaps, a large amount of infrastructure and services is being built right now, offering good opportunity to build in resilience and risk reduction. . It is essential we are prepared for the future building capabilities, harnessing technology and data to anticipate risk and ceasing opportunities to act early and manage uncertainty.

The GAR2024 report looks at present and future trends, showing how forensic analysis can enable more targeted and more effective risk reduction. As such, this report encourages the application of similar approaches by risk managers, development practitioners, and researchers alike. We can all learn from disasters in our own contexts to reduce immediate and systemic risks. The authors of this report hope that wise and able governments will see this as a timely opportunity to hard wire-resilience into our future cities, communities, and environments for the benefit of current and future generations.

179 UNDRR, 2019; Sillman, 2021
180 Oliver-Smith et al, 2016; McDermott et al, 2022; International Science Council (ISC), 2023.

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