Executive Summary

An EPIC Response:

Innovative Governance for Flood and Drought Risk Management

GREG BROWDER, ANA NUÑEZ SANCHEZ, BRENDEN JONGMAN, NATHAN ENGLE, EELCO VAN BEEK, MELISSA CASTERA ERREA, STEPHEN HODGSON

THE WORLD BANK
IBRD • IDA | WORLD BANK GROUP

GFDRR
Global Facility for Disaster Reduction and Recovery

GWSP
GLOBAL WATER SECURITY & SANITATION PARTNERSHIP

Deltares

About the Water Global Practice

Launched in 2014, the World Bank Group's Water Global Practice brings together financing, knowledge, and implementation in one platform. By combining the Bank's global knowledge with country investments, this model generates more firepower for transformational solutions to help countries grow sustainably.

Please visit us at www.worldbank.org or follow us on Twitter at @WorldBankWater.

About Deltares

Deltares is an international research institute focused on climate-resilient water resources management. Throughout the world, Deltares works on smart solutions, innovations, and applications for society and the environment in deltas, coastal regions, and river basins.

Deltares works closely with governments, the private sector, research institutes, and civil society organizations. Our mission is to Enable Delta Life

Please visit us at https://www.linkedin.com/company/deltares

About GWSP

This publication received the support of the Global Water Security & Sanitation Partnership (GWSP). GWSP is a multidonor trust fund administered by the World Bank's Water Global Practice and supported by Austria's Federal Ministry of Finance, the Bill & Melinda Gates Foundation, Denmark's Ministry of Foreign Affairs, the Netherlands' Ministry of Foreign Affairs, the Swedish International Development Cooperation Agency, Switzerland's State Secretariat for Economic Affairs, the Swiss Agency for Development and Cooperation, and the U.S. Agency for International Development.

Please visit us at www.worldbank.org/gwsp or follow us on Twitter #gwsp.

About GFDRR

The Global Facility for Disaster Reduction and Recovery (GFDRR) is a global partnership that helps developing countries better understand and reduce their vulnerabilities to natural hazards and adapt to climate change. Working with over 400 local, national, regional, and international partners, GFDRR provides grant financing, technical assistance, training and knowledge sharing activities to mainstream disaster and climate risk management in policies and strategies. Managed by the World Bank, GFDRR is supported by 34 countries and 9 international organizations.

Please visit us at www.gfdrr.org or follow us on Twitter @GFDRR

An EPIC Response: Innovative Governance for Flood and Drought Risk Management

GREG BROWDER, ANA NUÑEZ SANCHEZ, BRENDEN JONGMAN, NATHAN ENGLE, EELCO VAN BEEK, MELISSA CASTERA ERREA, STEPHEN HODGSON

THE WORLD BANK
IBRD • IDA | WORLD BANK GROUP

GFDRR
Global Facility for Disaster Reduction and Recovery

GWSP
GLOBAL WATER SECURITY & SANITATION PARTNERSHIP

Deltares

1818 H Street NW, Washington, DC 20433

Telephone: 202-473-1000; Internet: www.worldbank.org

Please cite the work as follows: Browder, Greg, Ana Nunez Sanchez, Brenden Jongman, Nathan Engle, Eelco Van Beek, Melissa Castera Errea, and Stephen Hodgson. 2021. “An EPIC Response: Innovative Governance for Flood and Drought Risk Management—Executive Summary.” World Bank, Washington, DC.

Design: Miki Fernandez

Cover photos: top/Capstoc; bottom/Heyfajrul

Photo: BassittART

Table of Contents

Acknowledgements

This report was prepared through a partnership between the World Bank (WB) and Deltares. The WB team was led by Greg Browder, Brenden Jongman, and Nathan Engle and includes Melissa Castera Errea, Stephen Hodgson, Natalia Limones, Sandra Knight, and John Carrey. The Deltares team was led by Ana Nunez Sanchez and Eelco van Beek, and includes Herman van de Most and Patricia Trambauer. David Rogers provided key insights and guidance throughout the study.

The report benefitted greatly from the strategic direction provided by WB management, including Jennifer Sara (Water Global Director), Sameh Wahba (Urban, Resilience, and Land Global Director), and Richard Damania (Sustainable Development Chief Economist). From Deltares, strategic direction was provided by Annemieke Nijhof (Managing Director), Toon Segeren (Director of Deltares International), and Bianca Peters (Resilience and Planning Department Head).

The team appreciates the detailed reviews provided by the following WB staff: Stephane Hallegatte (Climate Change); Erwin de Nys, Yukio Tanaka, and Satya Priya (Water); Ana Campos and Oscar Ishizawa (Disaster Risk Management); Paola Agostini (Environment); and Asa Giertz, Holger Kray, and Ademola Braimoh (Agriculture).

We are grateful to the following partners in reviewing and shaping the report: Robert Stefanski (Integrated Drought Management Program, WMO); Giacomo Teruggi (Associated Program on Flood Management, WMO); Valentin Aich and Danielle Gallard Picher (Global Water Partnership); Cody Knutson and Mark Svoboda (U.S. National Drought Mitigation Center, University of Nebraska-Lincoln); Toshio Koike (International Centre for Water Hazard and Risk Management, ICHARM); Daniel Tsegai (Secretariat to United Nations Convention to Combat Desertification, UNCCD); Jeroen Aerts and Joyeeta Gupta (University of Amsterdam); Andrew Allan (University of Dundee); Willem Ligtvoet (Netherlands Environmental Assessment Agency); and Jos Timmerman and Paul Sayers.

Support for the case studies presented in the report include Candido Cabrido and Joop Stoutjesdijk (Philippines); and Onesmo Sigala, Jacqueline Tront, and Yohannes Kesete (Tanzania).

We would also like to thank the following WB staff who contributed to the report: Roohi Abdullah, Diego Arias, Sarah Keener, Toyoko Kodama, Virginie Laroche, Niels Holm-Nielsen, Jason Russ, Marie-Adele Tchakounte Sitchet, Toshiro Sonoda, and Monika Weber-Fahr. Key contributors from Deltares include Arno Nolte, Marcel Marchand, Jarl Kind, Kymo Slager, and Bregje van Wesenbeeck.

Miki Fernandez provided the layout and design for the report and Stephanie Ijff supported with conceptual illustrations. Meriem Gray, Pascal Saura, Ayse Boybeyi, Eric Barrett, Li Lou, and Erika Vargas (WB) and Jaqueline Vink and Brigitte Verhagen (Deltares), provided invaluable support for the production and dissemination of this report.

We are pleased to recognize the generous funding provided through the Global Water Security and Sanitation Partnership (GWSP) to produce this report, as well as the support of the Global Facility for Disaster Reduction and Recovery (GFDRR).

About the Authors

Greg Browder, is a Lead Water Resources Management Specialist at the World Bank. During the preparation of the report he served as the Global Lead for Water and Resilience.

Ana Nunez Sanchez, J.D. is a Planning and Institutional Expert at Deltares and leads the Deltares' Adaptation and Implementation Research Program.

Brenden Jongman is a Senior Disaster Risk Management Specialist at the World Bank and leads the World Bank's Community of Practice for Nature Based Solutions.

Nathan Engle is a Senior Climate Specialist at the World Bank and co-leads the World Bank's Drought Resilience Community of Practice.

Eelco van Beek is a Water Resources Management Expert at Deltares and Emeritus Professor at the Delft University of Technology and the University of Twente, in the Netherlands.

Stephen Hodgson, J.D. is an independent environmental lawyer based in Belgium.

Melissa Castera Errea is the Coordinator for the Water Resources Global Solutions Group at the World Bank.

Foreword

Floods and droughts are some of the most tangible – and devastating – consequences of the climate crisis. They increasingly affect communities across the planet. The toll in human suffering and in economic costs is staggering. It is crucial that societies adapt and that governments prioritize, accelerate, and scale up their response mechanisms in the coming decade.

Societies have long struggled to prepare for and respond to floods and droughts - two hydrological extremes that can happen to the same country and at the same time. Climate change is driving more moisture into the atmosphere, resulting in 'hyper-charged' storms, heavy rains, and more intense dry spells. In many parts of the world, these changes to the hydrological cycle mean stronger and longer flood and drought periods, and in other areas, individuals are experiencing these hazards to a significant degree for the first time in living memory. Worldwide, it is difficult to point to a region or country that will not face more challenges managing these extremes in the years to come.

Countries can harness the power of water for development while avoiding the human suffering, economic losses, and ecological degradation that is associated with the hydrological cycle on overdrive. And societies can learn how to embrace the inevitability of floods and droughts, and the drastic alternations between them. This requires innovative governance and risk management approaches that navigate uncertainty, protect communities, economies, and ecosystems, reduce duplication, and improve efficiency of public resource use.

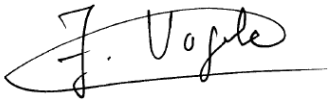
The EPIC Response Framework presented in this report offers a path forward for governments to manage these risks more comprehensively and systematically. It prioritizes the need for a "joined-up" government effort – one that does not rely on a single national lead agency and that does break siloes of single agencies mandated to address isolated parts of the interrelated challenges of floods and droughts.

Critical to the framework is its "whole of society approach", inclusive and representative of the needs of all of society. This means more effective public participation, and greater government effort to absorb citizens' views, especially those who are systematically underrepresented, such as women, minorities, elderly, and the poor. Floods and droughts typically hit groups in vulnerable situations the hardest. Traditionally, loss of assets or reduction in GDP are the measures of impact. But the poor have few assets and are underrepresented in this calculus. The EPIC Framework calls for a broader view that also considers their loss of "well-being" and potential intergenerational consequences.

We hope that governments, along with the countless individuals and organizations working on adaptation and resilience to climate change and disaster risk management, will find the EPIC Framework useful to meet their rising resilience challenges. We also hope that it serves as a rallying cry for governments and other development partners to focus on managing these risks in tandem across the hydrological spectrum and reaping the benefits of this innovative governance approach along the way. This is not to say that implementing the EPIC Response Framework will be easy. Far from it. But the way forward is to invest in strong partnerships and cooperation, at all levels, to stimulate the exchange of knowledge, tools, and resources to systematically prepare for and respond to floods and droughts in the coming decades.

So, while climate change and COVID-19 are compounding many challenges, they also present an unprecedented opportunity. Amid record spending to spur a recovery from the pandemic, we have a chance to leverage these investments towards green, resilient, and inclusive development that reduces rather than further exacerbates our societies' vulnerability to climate risks. Let's seize that opportunity.

Kitty van der Heijden
Director General for International Cooperation
Ministry of Foreign Affairs
The Netherlands



Juergen Voegele
Vice President for Sustainable Development
The World Bank

Trapped during the 2015 flood, Grogol Street, Jakarta, Indonesia. Photo: © danikancil.

A farmer in Mahrasthra, India showing the impact of drought on his and hundreds of other farmers' crops. Photo: © Dreamstime Agency | Dreamstime.com.

1. The Challenge

One of the most pressing and complex challenges that governments around the world now face is managing the risks of floods and droughts. These natural hazards take a staggering toll, both in human suffering and in economic costs. Over the last decade, the overall toll from both floods and droughts adds up to tens of thousands of deaths, billions more people affected, damages of more than a trillion dollars (US), and increased geopolitical instabilities.[1]

In addition to the direct costs of floods and droughts in lives lost, structures damaged, and businesses impacted, these natural disasters have huge indirect and social costs. Poor and marginalized people tend to be the most vulnerable, the hardest hit, and the slowest to recover. In cities, they are more likely to live in informal settlements on floodplains or on hillsides prone to landslides. In rural areas, droughts that strike poor farmers can impair health, reduce levels of education, and lower families' wealth and health for generations, perpetuating poverty and contributing to migration and political unrest. In addition, floods and droughts can disrupt global food supply chains and cause the loss of the invaluable services that ecosystems deliver, such as the supplies of clean water provided by healthy forests or wetlands.

What makes this challenge even more urgent now is climate change. With every small rise in global temperatures, the planet's hydrological cycle speeds up and packs a larger punch. Storms and rainfall events are becoming more extreme and deadly; droughts are increasing in frequency, intensity, duration, and geographical size. The enormous 1.3 meter rainfall from Hurricane Harvey, which submerged much of the Houston region of the United States in 2017, was as much as 38 percent greater than it would have been without climate change.[2] Similarly, the record-breaking heatwave and drought in Europe in 2019, which killed forests, crippled crops, and sent temperatures soaring to (45.9°C) in France, was made at least five times more likely by climate change.[3] Those events are just two of the many harbingers of the climate impacts that lie ahead.

Moreover, not only are storms and droughts becoming more extreme, but climate zones are shifting all around the world and watersheds are changing, bringing profound impacts on regions' hydrology. To emphasize the duality of floods and drought, the report often uses the term "hydro-climatic risks," which is explained in the box below. We need to reshape policies to cope with the growing threats of floods and droughts—and to accelerate the policy cycle itself to keep up with the constantly changing conditions.

In the last few decades, some countries have made significant strides in their efforts to better manage flood and drought risks. Yet the sobering truth is that many governments still have important gaps and limitations in their policies to manage current risks, let alone the more extreme events that climate change is bringing. To cite a key shortcoming, while government agencies typically focus on separately addressing flood and drought management within their own mandates, with varying degrees of effectiveness, rarely do they collaborate to synergistically reduce hydro-climatic risks. Moreover, these agencies are increasingly suffering whiplash as they alternate from one type of disaster to another, rather than appreciating that floods and droughts are just opposite ends of the same hydro-climatic spectrum.

This siloed approach makes it much harder to seize key opportunities for protecting against both flood and drought hazards, such as protecting wetlands and forests. Those natural areas can then both soak up excess water, reducing the threat of flooding, and recharge groundwater, offering more life- and crop-saving water in times of drought. In fact, some current measures aimed at one hazard can actually worsen the other. While levees can successfully reduce flooding, they also may cut off flows into the groundwater, increasing water shortages during droughts.

Box 1 The Concept of Hydro-Climatic Risks

Hydro-climatology is broadly defined as the influence of climate upon the waters of the land. It considers the whole hydrological cycle and the interactions between weather, watersheds, and water. Although droughts and floods are colloquially referenced as too little or too much water, the actual processes are much more complicated and often inter-related. For example, land degradation can increase both flood and drought hazards, and multi-purpose reservoirs can decrease both flood and drought hazards. Hence the term "hydro-climatic risks" is used to encourage a more holistic understanding of flood and droughts.

2. A New Perspective

A new and better approach to manage the growing risks of floods and droughts on a warming planet is thus urgently needed. This report offers such a new approach. It is intended to raise awareness of this enormous challenge and to provide new insights and inspiration for national governments, international organizations, civil society, and the research community. It also sets out a vision of how governments can deal with these challenges through innovative governance and policies, and it provides a menu of possible solutions, offering a practical and detailed framework for helping governments improve their flood and drought management systems and create a safer, more prosperous future for the world's 7.7 billion people. In addition, it provides an explicit focus on the need to adapt to climate change and prepare for its impacts, and can help inform countries' National Adaptation Plans, which alongside Nationally Determined Contributions, are highlighted in the 2015 Paris Climate Agreement.

The approach described in this report has the potential to not only reduce the toll in human suffering from increasingly severe floods and droughts, but also to bring significant economic benefits. Those include reduced economic damages from extreme events, improved productivity, less duplication, greater general economic growth, and reduced inequities—creating a strong business case for innovative governance.

The extensive policy research and the four detailed case studies (of Tanzania, the Philippines, California, and the Netherlands) underlying this report together show that all these benefits can be realized by following three overarching principles. First, it is essential to engage all parts of society, from government agencies and universities to the private sector and individuals from marginalized communities, in a "whole-of-society" approach. Second, floods and droughts should be seen through the lens of "hydro-climatology" as two sides of the same coin and addressed together when appropriate. Third, the multiple agencies that manage key functions like disaster risk management, water resources, meteorology, agriculture, and natural resources management can no longer work alone, exclusively pursuing their own independent mandates. Instead, they must coordinate and collaborate in what might be called "joined-up government" operating as a single entity to manage the complex and interrelated challenges posed by floods and drought and presenting a single front to the citizens they serve.

Since national government leadership is essential in leading a whole-of-society effort addressing hydro-climatic risks, the report focuses on the role of national government agencies in implementing and collaborating across a broad spectrum of programs. The graphic below shows the general mandates of the various sector agencies with respect to flood and drought risk management. Each agency has a specific mandate related to floods and droughts which it must perform effectively. However, this is not enough: the agencies also must appreciate how their activities fit into an overall framework for hydro-climatic risk management and collaborate as required. Such collaboration will require new forms of governance in which no single agency has a lead role. Instead, the agencies must work together in a joined-up government to face the challenge posed by a changing climate.

FIGURE 1 National Agency Roles for Hydro-Climatic Risk Management

Hydromet

Provides information for water resources and floodplain management. Leads flood and drought forecasting. Supports agriculture with agro-hydro advisory services.

WRM

Oversees planning and operation of water resources infrastructure. Regulates water allocations and strategic use of groundwater to help mitigate droughts. Key role in flood and drought response.

DRM

Lead coordinating agency for flood, and sometimes drought, disaster response. Provides leadership in floodplain management. Works with other agencies to mitigate risks.

Agriculture

Promotes healthy watersheds through sound agricultural policies and climate-smart agriculture. Helps boost farmer incomes and resilience. Key role in drought response. Collaborates with natural resources and WRM on watershed management

Natural resources management

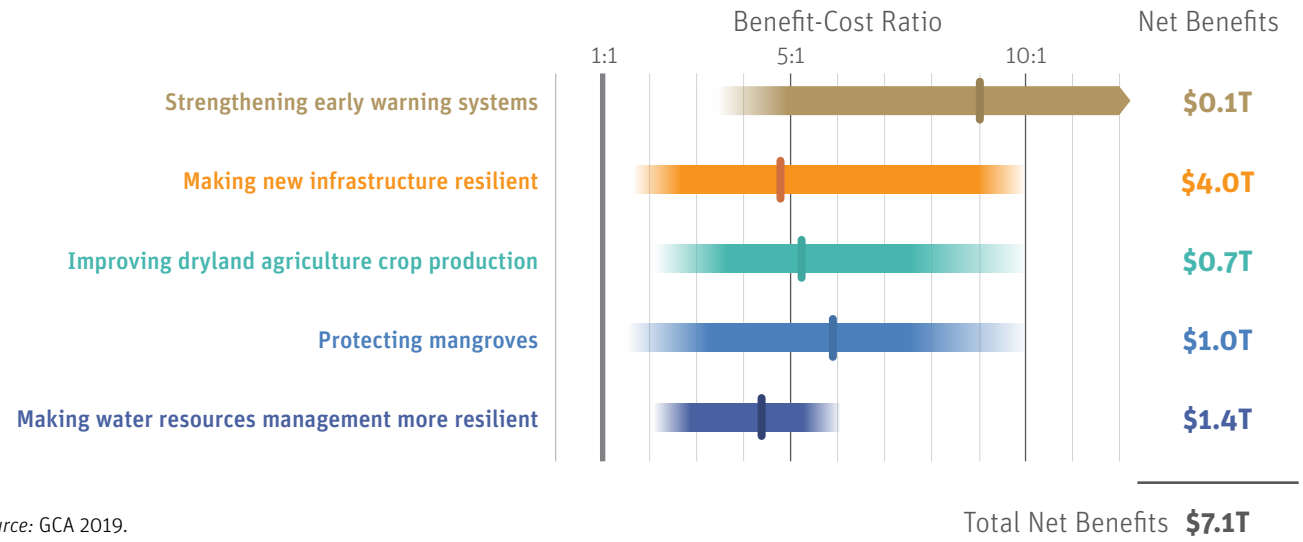
Promotes healthy watersheds by sustainably managing forests, wetlands, and coastal barriers. Collaborates with agriculture and WRM on watershed management.

The different EPIC Response programs, implemented by a variety of agencies, interact together and ultimately determine the final social, economic, and environmental impacts caused by extreme hydro-climatic events.

The research presented in this report indicates that a joined-up national government approach with a whole of society effort to better manage hydro-climatic risks can bring many benefits. The approach reduces the social, economic, and environment impacts associated with extreme hydro-climatic events. It helps ensure efficient use of public resources by avoiding duplication and promoting synergy between different government programs. Finally, it promotes equity by protecting most vulnerable groups in society. **Figure 2** from the Global Commission on Adaptation (GCA)[4] shows the tremendous payback from investing in adaptation—these returns on investment will only be realized, though, if governments adopt smart policies, and that is what this report is about.

This approach also opens opportunities to tap into the potential ecological and economic benefits associated with managing extreme events. Earth is a dynamic planet and ecosystems have evolved to deal with the full spectrum of hydro-climatic conditions. The extreme events that generate natural disasters (if not properly managed) also act as important drivers to refresh and sustain natural systems. Floods deposit rich silt on floodplains, creating fertile soil and productive farmland. Heavy bouts of rainfall can increase crop yields and boost hydroelectric power production. Even droughts play an important ecological role. For example, droughts create the conditions needed for wildfires that help to reduce forest understory and rangeland brush, and to stimulate seeds to germinate.

FIGURE 2 Benefits and Costs of Illustrative Investments in Adaptation



Source: GCA 2019.

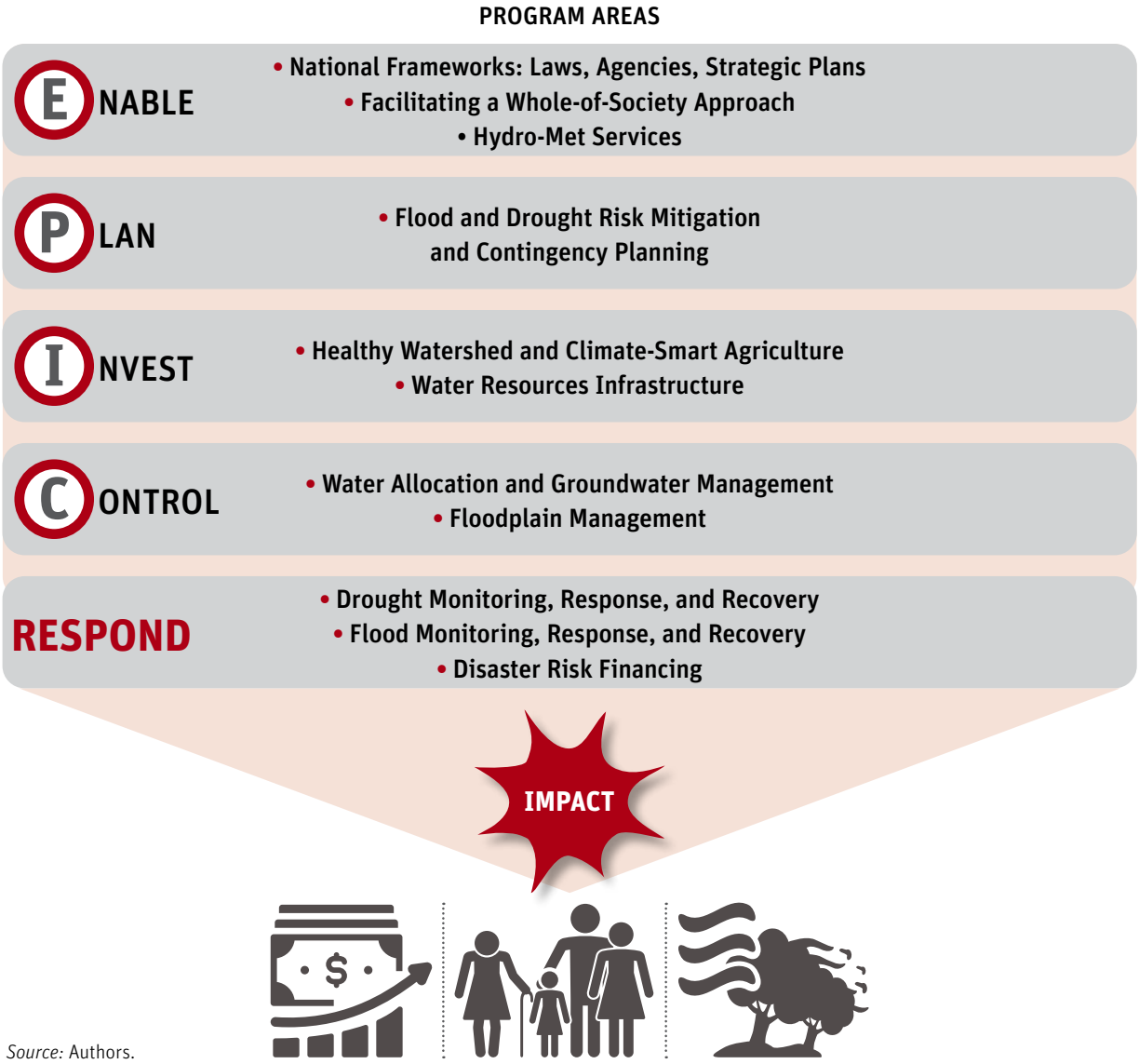
The returns on individual investments in climate adaption will depend in large measure on the effectiveness of the hydro-climatic risk management system.

3. The Framework for Action

The report provides an "EPIC Response Framework" to help facilitate a joined-up government effort. The basic elements include an *enabling* environment of policies, laws, agencies, strategic plans, and information; *planning* at all levels to prioritize risk mitigation measures; *investing* in watersheds and water resources infrastructure; *controlling* the use of land and water resources to reduce exposures and vulnerabilities; and *responding* better to extreme events. The first letters of each of the first four elements, plus the word "response," create the apt term "EPIC Response." That term provides a guide for the many agencies that must be involved—water resources management, disaster risk management, meteorology and hydrology, agriculture, natural resources management, social protection, and finance.

Putting an EPIC Response (see **Figure 3**) into practice will require actions grouped into eleven different program areas

FIGURE 3 The EPIC Response Framework



Source: Authors.

that are presented in this Executive Summary. The Main Report provides information on more than 30 specific programs that are grouped into these eleven program areas.

The EPIC Response Framework helps illustrate three key points. First, these different programs, implemented by a variety of agencies, interact together and ultimately determine the final social, economic, and environment impacts caused by extreme hydro-climatic events. The interactions and influences among these programs generally cascade downward, as shown in the graphic. But it's also important to understand that these interactions and influences are complex and can move in both directions. As will be explained in the paragraphs below, the challenges faced by any given program are profoundly affected by the effectiveness of the programs above it in the EPIC Response Framework.

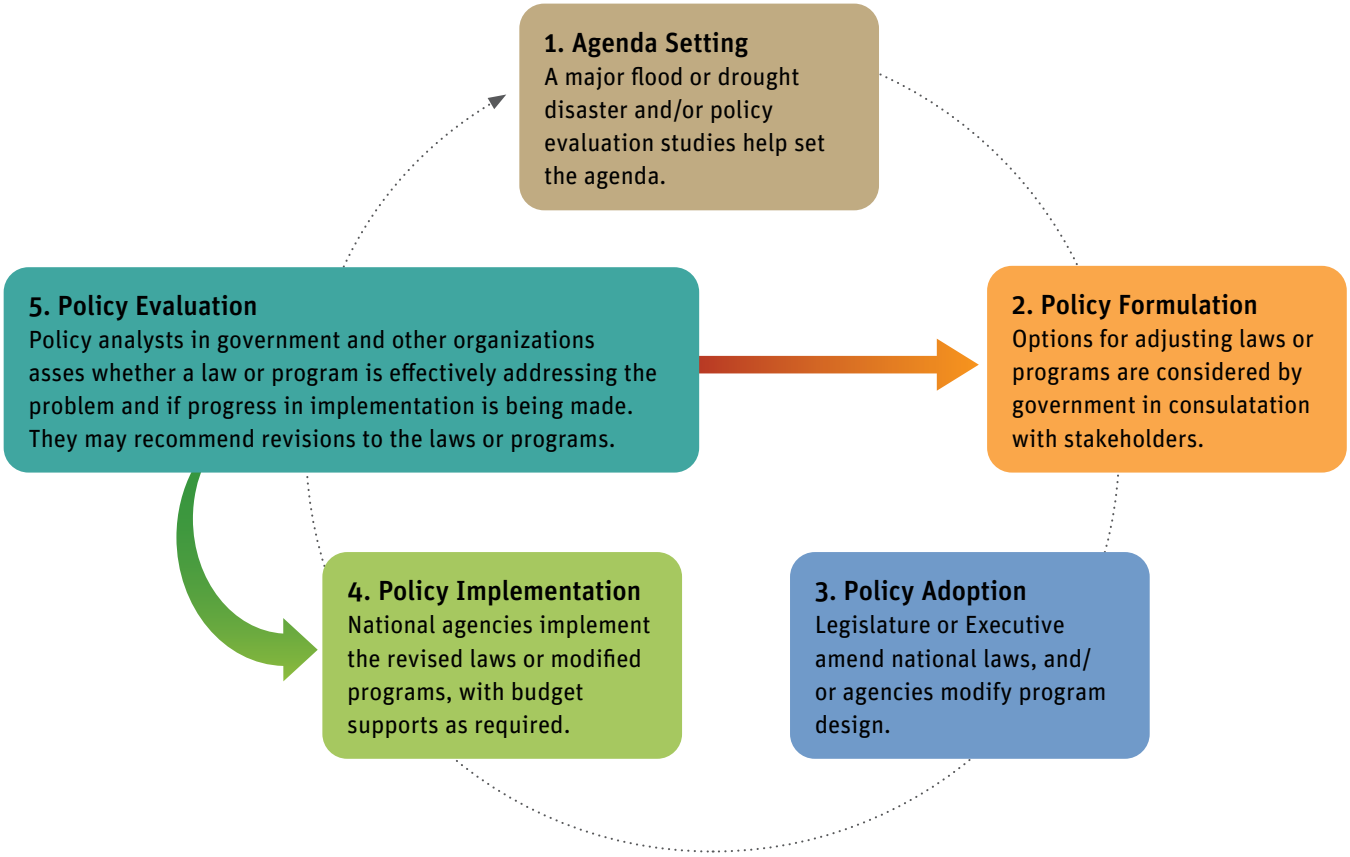
Second, the EPIC Response Framework helps to identify areas where agencies can collaborate to create synergies and produce more value. For example, hydro-met agencies can work with disaster risk management (DRM) and water resources management (WRM) agencies to produce better flood warnings. Natural resources agencies can help to improve watershed quality and actively participate in the formulation of WRM agency-led river basin plans. WRM and DRM agencies can jointly help local governments improve floodplain management. Effective drought monitoring and response requires collaboration between hydro-met, WRM, and agriculture agencies. The Main Report highlights numerous areas where agencies can and should collaborate on reducing hydro-climatic risks. The concept of collaboration goes beyond mere coordination. Coordination implies avoiding overlaps; in some cases a powerful agency may even attempt to use coordination to assert its dominance over another agency. Collaboration means different agencies working together on a shared agenda, with each agency contributing according to its area of expertise as an equal partner. A joined-up government needs to find innovative ways of working together to foster this type of collaboration.

Third, the different programs in the EPIC Response Framework, and the level of collaboration between different agencies, are constantly evolving. The hope is that over time, the result will be ever better hydro-climatic risk management. Managing hydro-climatic risks is complex, and there are no simple solutions. There are also considerable challenges to implementing an EPIC Response Framework. The level of economic development has an important influence on the amount of financial and human resources that a government can employ to support the set of programs in the Framework. Entrenched political or economic interests may also stymie efforts to improve flood and drought risk management efforts.

However, with a sound public policy process, as outlined in in **Figure 4**, governments can constantly improve the way they manage flood and drought risks. The term policy is used in a broad sense to refer to important government decisions related to laws, strategies, and programs. Of particular importance are the evaluation activities, whether it be an evaluation of a specific program or a more systematic analysis of how a country is managing flood and drought risks. Structured evaluations and vigorous policy debates allow for real progress to be made. It is, however, a race against time. As climate change accelerates, so also must the public policy process as governments continually incorporate lessons and adapt to a changing world.

Individual chapters in the Main Report are structured around the EPIC Response Framework program areas. They offer a practical guide and framework that governments can draw from to meet the challenge of reducing risks from floods and droughts, and to take advantage of the opportunities that improved collaboration provides. Those eleven program areas, and the roles of the national agencies responsible for overseeing their implementation, are summarized in the following sections.

FIGURE 4 Generic Public Policy Process Applied to Hydro-Climatic Risk Management



Source: Authors adaptation from Howlett and Ramesh (1995)[5]

The public policy process for hydro-climatic risk management has to speed up as climate change accelerates.

4. Fostering an Enabling Environment

The E in the EPIC Response

National Frameworks

National frameworks are composed of laws, agencies, and strategic plans that enable the various programs in the EPIC Response Framework to function effectively. ***The key message of the report is that hydro-climatic risk management does not have a standalone national framework, rather it is a combination of different national frameworks—hence the need for close collaboration among different sector agencies.***

For flood risk management, DRM and WRM national frameworks play a prominent role. Agriculture, WRM, and DRM national frameworks are central for drought risk management. And of course, all the national frameworks depend on quality hydrological and meteorological services. National governments should consider creating a permanent intersectoral National Drought Committee, along with standalone national drought plans, to help prepare for and respond to the widespread pervasive impacts of droughts.

Since 2011, the United Nations Framework Convention on Climate Change (UNFCCC) has highlighted the importance of preparing national climate adaptation plans. The 2015 Paris Agreement outlined the expectation that all countries—developed and developing—will prepare and implement national adaptation plans (NAPs) in addition to their Nationally Determined Contributions (NDCs) for reducing greenhouse gas emissions.[6] The NAP is built upon multiple national frameworks and thus presents an ideal opportunity to apply the EPIC Response Framework.

In evaluating the effectiveness of these national frameworks, governments should consider asking several key questions. Do those frameworks create a culture that fosters collaboration among equals, not just coordination dominated by more powerful agencies? Do those agencies view floods and droughts as being inextricably linked and thus crucial to manage together? Do those national frameworks lay the foundation for managing both land and water to increase resilience in the face of droughts and floods, and for improving sustainability? Do the frameworks provide adequate social safety nets to reduce the human and economic toll from emergencies? And do the national frameworks work seamlessly with sub-national and local governments to bring improved management to all regions and communities?

Tanzania is one country that grappled with these questions after a prolonged drought from 1998 to 2005 caused widespread crop failures, livestock losses, food shortages, and the rationing of hydroelectric power and water because of plunging water reservoir levels.[7] The result was the Water Resources Management Act of 2009, which created the Ministry of Water and Irrigation to oversee the management of both floods and droughts, ensuring that measures taken to reduce the risks of one hazard don't raise risks of the other. The Act includes important provisions to improve the safety of dams and maintenance of dikes, to control stormwater in cities, to oversee water sales to prevent shortages, and to foster cooperation with local governments on their own flood plans. The case study shows that while Tanzania has made significant advances, it is still in the early stages of true integrated water resources management. This is to be expected as the report emphasizes that developing effective programs to deal with floods and droughts is an evolutionary and recurrent process, in which an enabling law is an important first step.

Consider how the Netherlands started on a long journey after a devastating 1953 flood. It first created the "Delta Works", which focused on developing gray infrastructure by putting in place an elaborate system of dams, storm surge barriers, and other protective measures. The Delta Works provided the necessary safety against flooding, but it also became apparent that more attention was needed for other functions of the water system, in particular the ecological value of the water bodies behind the defense system. A new Water Act in 2009 and the establishment of an independent Delta Commission in 2012 helped to bring together experts on water management with representatives from all levels of government and society to ensure that benefits reached as many people as possible. These steps, among others, brought a greater realization of the power of combining gray and green infrastructure, and led among others to the "Room for the River" program, which further cut flood risks by allowing more space for floodwaters while also restoring natural habitats.

As demonstrated in the Netherlands, national frameworks evolve over time as a country gains experience, deepens technical knowledge, develops economically, and hopefully improves its overall governance. It is not an easy task. There are many examples of ambitious laws that are promulgated

but not fully implemented due to lack of resources, commitment, or the opposition of entrenched interests. A joined-up government effort with multiple government agencies collaborating to reduce hydro-climatic risks is a vision that, even in the most advanced countries, is seldom truly realized as agencies vie with each other for budget and influence. Nevertheless, there is no alternative but to move in this direction. The EPIC Response Framework provides a roadmap for progress.

Whole of Society Approach

Programs to reduce flood and drought risks are most effective when they represent the needs of all of society. National governments, therefore, should strive to change the organizational culture of every agency to include social expertise as well as technical knowledge, ensuring that agencies are more adaptive and flexible, and able to work with and respond to the needs of society. Of particular importance is building alliances with local governments, which are the natural partners of national agencies in the management of hydro-climatic risks. This also means inviting greater public participation in policy decisions, especially from those who might be systematically underrepresented, such as women, minorities, the elderly, and the poor.

History offers strong reminders that disasters caused by natural hazards typically hit poor and marginalized communities the hardest. Traditionally, disasters have been measured in terms of asset losses. That underestimates the impacts on the poor, who obviously have fewer assets and are generally not well prepared to respond to and recover from disasters. A more comprehensive perspective is to consider the "well-being losses" that explicitly take into account the recovery and reconstruction process at the household level. A study published in 2020 estimated that the average annual well-being losses due to disasters in the Philippines is US$3.9 billion per year, more than double the asset losses of US$1.4 billion.[8] Using the metric of "well-being" to help guide hydro-climatic risk management actions often changes the calculus to better protect the interests of the poor.

Some countries have begun to broaden the inputs into their national programs. The Philippines has created local disaster management councils that include public officials and representatives from various parts of society, and that take the lead in preparing for, responding to, and recovering from extreme events.

An effective whole-of-society approach also acknowledges that much of the expertise for managing flood and drought risk and adapting to a changing climate exists outside of national agencies, in places like universities and the private sector. Taking advantage of these resources can accelerate innovation in both policies and technologies, and has the potential to both boost economic growth and improve environmental sustainability. It is time for agencies to work more collaboratively with the scientific community to foster both science-informed policy as well as policy-informed science. The ability to access all types of publicly produced or shared information—sometimes referred to as open data—helps to unlock the potential of a whole-of-society approach. The European Commission's 2019 Directive on Open Data (2019/1024), for example, aims to promote the use of open data and stimulate innovation in products and services by stripping away barriers to the use of new digital technologies, such as artificial intelligence. That is expected to spur economic growth and improve environmental management.

Hydrological and Meteorological (Hydro-Met) Services

Accurate and timely climate, weather, and water information is the bedrock on which effective disaster mitigation and response plans are built. Precise and advanced warnings of looming threats from tropical cyclones and other major storms make it possible to evacuate or protect people in the path of tropical cyclones. The Philippines case shows that such warnings helped save thousands of lives when super-typhoon Goni struck the country in 2020. Drought monitoring also relies on meteorological and hydrological information, combined with on-the-ground monitoring to assess impacts and risks as droughts evolve over time.

In addition, hydro-met services provide information for water resources planning and infrastructure design, which also need to consider climate change. About every six years, California produces a "climate change assessment report" that provides the scientific foundation for understanding

The report emphasizes that developing effective programs to deal with floods and droughts is an evolutionary and continuous process, for which enabling laws provide the foundation.

Albay Province, Philippines. 1st Nov, 2020. A man looks at a house submerged in floodwaters brought by the heavy rains from typhoon Goni. Photo: Xinhua / Alamy Stock Photo.

climate-related vulnerabilities at the local scale and for informing resilience actions. The assessments directly inform state policies, plans, programs, and guidance to promote effective and integrated action to safeguard California from climate change. The most recent 2018 assessment is striking in its urgency:[9]

> "California is one of the most "climate-challenged" regions of North America; its historical climate is extremely variable, and climate change is making extreme conditions more frequent and severe. California's temperatures are already warming, heat waves are more frequent, and precipitation continues to be highly variable. Since its Third Climate Change Assessment in 2012, California has experienced several of the most extreme natural events in its recorded history: a severe drought from 2012-2016, an almost non-existent Sierra Nevada winter snowpack in 2014-2015, increasingly large and severe wildfires, and back-to-back years of the warmest average temperatures."

The role of national meteorological services (NMS) is rapidly changing from single provider to facilitator, as they tap into the "global weather enterprise." This consists of global and regional forecasting centers, the private sector, which is rapidly developing new tailored weather products, and academia, which is on the cutting edge of weather and climate research. To generate more value for society, NMS need to combine efforts with WRM, DRM, and agriculture agencies to provide integrated services, such as impact-based flood forecasting, drought monitoring, and agrometeorological services that combine information on hazards, impacts, and actions.

Accurate predictions of weather conditions expected in days or weeks ahead can guide farmers' choices about when or what to plant and when to irrigate or fertilize—a strategy that has cut crop losses and raised incomes in Tanzania.[10] National hydrological services (NHS) provide real-time data on river flows, reservoir and groundwater levels, and water use to help provide accurate flood forecasts, along with more optimal strategies for crop irrigation or hydroelectric power generation. And floodplain maps updated to take into account the rising seas and intensifying storms caused by climate change can be used to prevent development in areas that will become increasingly vulnerable, thus avoiding future human and economic losses.

Given the enormous value of this meteorological and hydrological information, governments need to invest in their NMS and NHS. They need state-of-the art equipment and, even more important, high-quality professional staff. The NMS and NHS also need effective strategies for communicating the information to those who need it. In one example, the Netherlands Water Management Center gets detailed meteorological information and forecasts compiled by the Royal Netherlands Meteorological Institute from satellite data and other sources. The Water Management Center combines that weather and climate information with actual and forecasted data on river discharges and water levels throughout the country. Then, when floods or droughts threaten, the Water Management Center brings together the government's water managers, the disaster response agency, local government leaders, and experts to hammer out the best actions for minimizing the potential dangers.

5. Planning to Reduce Risk

The P in the EPIC Response

Flood and Drought Risk Mitigation and Contingency Planning

A national framework, a whole-of-society-approach, and timely meteorological and hydrological information together create the necessary *enabling* environment for effectively managing the risks of floods and droughts.

Another crucial element is *planning*. Water resources management (WRM) agencies need to encourage harmonized planning at multiple levels to help mitigate flood and drought risks. As shown in **Figure 5**, in many cases integrated river basin planning is the instrument of choice for providing an overall framework for flood and drought management. Cities and irrigation service providers also need individual plans for mitigating floods and droughts—and for responding to events when they occur through tailored contingency plans. Integrated coastal zone management (ICZM) planning is also essential to reduce flood risks, and these efforts are often spearheaded by an environmental or natural resources agency.

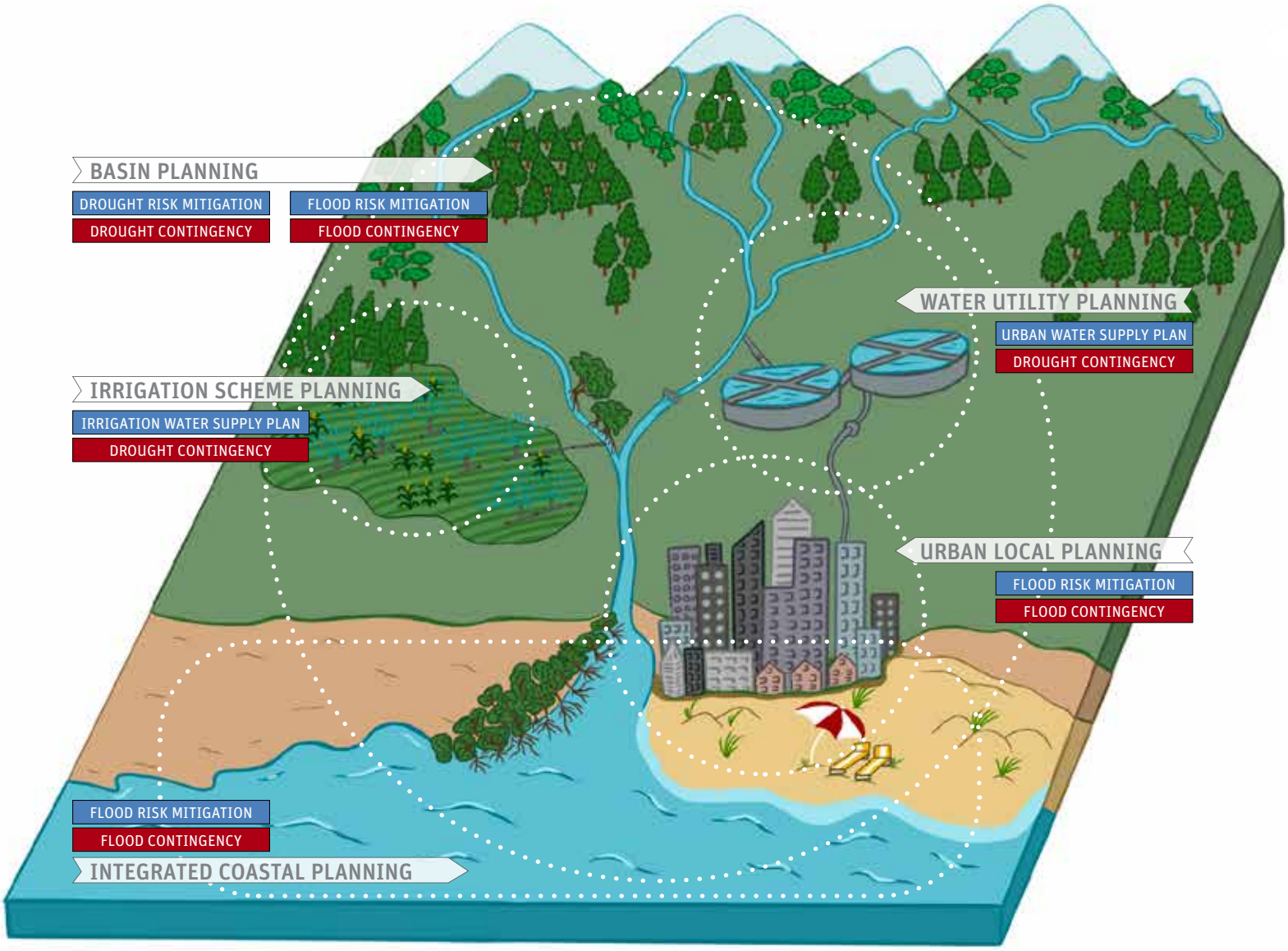
All these plans need to explicitly consider the growing impacts of climate change, such as more extreme precipitation events, more intense droughts, higher storm surges, rising seas, and saltwater intrusion. Under Tanzania's 2009 Water Resources Act, for example, six of country's Basin Water Boards prepared comprehensive basin water resources management plans. In 2019, the World Bank worked with three of these Boards to test their basin plans using multiple climate scenarios. The basin plans were then adjusted to be more robust and offer more flexibility in the face of an uncertain climate future—including emphasizing the importance of managing groundwater as a strategic reserve during droughts.

It's also important to build in flexibility, regularly updating these plans in an accelerated policy cycle to reflect new knowledge, lessons learned, and new climate conditions. One such mechanism is in California, where water utilities are required to prepare new Urban Water Management Plans every five years. This has prompted water utilities to increase their efforts in water conservation and wastewater reclamation to help meet their future water needs.

Flood and drought risk mitigation and contingency planning at multiple nested levels is hard to achieve in practice. In less advanced countries, river basin plans are often formulated by WRM agencies with limited linkages to other agencies, cities, or agriculture. Moreover, in some cases the plans may be focused on infrastructure development, without considering the broad array of actions to mitigate flood and drought impacts. Unfortunately, there are many cases of river basin plans being ineffective instruments for developing and managing water resources. The remedy to these shortcomings is to systematically assess the effectiveness of planning exercises and recognize that it is an evolutionary process that requires constant adjustments.

Wetlands serve as green infrastructure, helping to reduce flood peaks and recharge groundwater. Photo: XPhoto 178846532 © Tsvibrav | Dreamstime.com.

FIGURE 5 Overview of Plans for Hydro-Climatic Risk Management



Flood and drought mitigation and contingency planning should be integrated into broader planning processes within a nested geographical context.

6. Investing in Healthy Watersheds and Water Resources Infrastructure

The I in the EPIC Response Framework

Healthy Watersheds: Agriculture and Natural Resources Management

At the global level, agriculture (including rangeland) accounts for 50 percent and forests account for 37 percent of habitable land.[11] From the broad perspective of weather, watersheds, and water—the core elements of hydro-climatology—agriculture and natural resources agencies must take the lead in protecting watersheds. Investments and policies to promote healthy watersheds are the first line of defense in reducing hydro-climatic risks. These investments harness the tremendous power of nature to manage and control water—so-called nature-based solutions.

Unfortunately, land degradation is undermining watershed health in many countries and is one of the greatest policy blind spots in domestic and global responses to hydro-climatic risk management. It is difficult to overestimate the importance of more sustainable land management. The United Nations Convention to Combat Desertification (UNCCD), which entered into force in 1994, calls for a concerted global effort to halt and reverse desertification and land degradation, and to sustainability manage our land resources. This will require a combination of sustainable agricultural and forestry policies, and programs to support climate-smart agriculture and sustainable forestry.

A key indicator of land degradation is soil quality. In 2015, the United Nation's Food and Agriculture Organization concluded that the majority of the world's soil resources are in fair, poor, or very poor condition and that problems are getting worse in far more places than those where there are improvements.[12] Land degradation not only reduces agricultural productivity, it also has adverse effects on other ecosystem services. Soil stores vast quantities of carbon dioxide, it cycles and stores key nutrients such as nitrogen and phosphorus, and most important for hydro-climatic risk management, it acts as the Earth's largest water filter and storage reserve, controlling the quantity and quality of freshwater resources.

While healthy watersheds can reduce hydro-climatic risks, degraded watersheds can generate vicious cycles that amplify these risks. Droughts can accelerate land degradation as vegetation withers and soil quality declines; meanwhile, land degradation makes droughts more difficult to manage as degraded soils have less capacity to store water. When floods come to degraded watersheds, soil erosion is increased, thus contributing to the vicious cycle. Climate change is expected to strengthen these negative feedback loops—meaning that an already large global problem could quickly become overwhelming if not urgently addressed.[13]

Land degradation is driven by a variety of factors depending on the specific context of a region. In some areas, poverty and overpopulation are driving vulnerable populations to move onto marginal lands, which quickly become degraded. Agricultural policies can also have a significant impact on land degradation, motivating farmers to grow inappropriate crops and utilize excessive amounts of water. To ensure food security and in conjunction with the Green Revolution starting in the 1960s, many governments adopted subsidy programs to promote the production of key staple crops, support poor farmers, and keep food prices low. This helped to both combat rural poverty and ensure food security. These subsidies took the forms of below-cost irrigation water, subsidized inputs such as fertilizers and seed, and crop price support programs. Although these policies did in fact increase the supply of cheap food, in many countries they also contributed to land degradation and water use inefficiency.[14]

Adjusting these agricultural policies to ensure the availability of nutritious food for the poor while reducing the environmental impacts of agriculture is the paramount agriculture policy imperative for the 21st century. It will not be politically easy, as many vested interests have emerged around existing subsidy regimes and governments are understandably wary about tampering with policies that may affect the production of food staples. Yet a Green Revolution 2.0 (GR2.0) is needed—and is emerging—to meet the world's food demands, ensure environmental sustainability, and meet the challenges of climate change.

By 2050, the global population is projected to increase by about one-third, and food production is expected to increase

by around 70 percent. GR 2.0 needs to not only increase basic cereal productivity (e.g. wheat, rice, and corn) to meet the demand for staples, but also to make more land available for higher value and more nutritious crops such as fruits and vegetables. In addition, it must allow for the movement of labor out of agriculture when other economic opportunities provide greater returns. GR 2.0 must also improve the tolerance of crops to stresses, both climatic and biotic (pest and disease). Improved varieties that are tolerant to drought or excess water would enhance smallholder productivity in marginal environments and provide tools to adapt to climate change.[15]

Agriculture agencies need to be the leaders in this transition to a GR 2.0. They can adjust agricultural policies to focus on improving productivity, gradually reducing subsidies that distort incentives for sustainable land management, and fund programs that support climate-smart agriculture. These programs can provide technical assistance and financial incentives for farmers and livestock producers to adopt practices that enhance soil and water productivity. For crops, this includes reducing or eliminating tillage and using crop residues and cover crops to protect the soil surface. Similarly, soils suffering from nutrient deficits can be restored and yields increased by returning crop residues and other organic matter to the soil, employing crop rotations with nitrogen-fixing crops, and making judicious use of organic and mineral fertilizers. Sound range management practices include rotational grazing and protection of riparian areas. Adding trees to fields in traditional "agroforestry" practices can stabilize riverbanks, protect against heatwaves and droughts by cooling the soil and increasing its capacity to hold water, and improve yields. Finally, the use of new technologies, such as a greater focus on precision agriculture, the internet of things (IoT) and the use of big data—sometimes referred to as agriculture 4.0—will play an indispensable role in the transition to a GR 2.0.[16]

After the Great Dust Bowl drought in the United States in the 1930s, the U.S. federal government launched a nationwide program of soil conservation. Today, the U.S. Department of Agriculture's National Resources Conservation Service (NRCS) provides technical assistance and grants for soil and water conservation. In California, local autonomous resource conservation districts tap into NRCS support and other funding to help farmers and ranchers sustainably manage their land.

Natural resources agencies, usually in the form of a forestry agency and/or environmental agency, are also on the frontlines of ensuring healthy watersheds through programs to conserve, restore, and sustainably manage forests, wetlands, and coastal resources. Coastal mangrove forests, for example, are particularly effective at taming storm surges that would otherwise send a wall of water rushing far inland, thus protecting coastal communities from flooding and shorelines from erosion. Marshes, bogs, and other wetlands act like giant sponges to soak up and slow floodwaters, and to make that water available when droughts strike. So do healthy forests.

Moreover, the benefits of healthy ecosystems extend far beyond reduced risks of floods and droughts. Mangroves provide crucial habitats for the shellfish and fish that sustain local economies and communities. Wetlands are nature's water treatment plants, removing the pollutants that could impair human health. Forests act as giant carbon sinks, helping to slow the rising concentrations of greenhouse gases in the atmosphere.

Agencies often face extraordinary political and economic pressures in their efforts to sustainably manage natural resources. Pressure to develop land for urban and agriculture use is often overwhelming as short-term economic interests vie with longer-term societal concerns. Natural resources agencies must employ all the tactics of a whole-of-society approach to build alliances that can withstand these pressures. They can do it through a portfolio of incentives, sanctions, and regulations. Most important, they must involve the communities that live on the land and depend on the natural resources.

Recognizing the importance of upland forests in hydro-climatic risk management, the Philippines created the National Greening Program with a goal of protecting and restoring 7.1 million hectares of degraded forest lands. So far, the country has successfully reforested 1.9 million hectares, not only reducing threats from floods and droughts, but also bolstering local timber operations and helping to lift people out of poverty.

Adjusting agricultural policies to ensure the availability of nutritious food for the poor while reducing the environmental impacts and greenhouse gas emissions is an imperative for the 21st century.

Water Resources Infrastructure

Another type of investment is in structures and systems that have been built to control and manage water—such as dams, groundwater wells, regional water pipelines, levees, dikes, flood control gates, and pump stations. Increasingly, this traditional gray infrastructure is being combined with green infrastructure, such as watershed protection above reservoirs, to form integrated green and gray infrastructure that provides higher levels of climate resilience and often lower costs. There is a clear need to increase funding for upgrading and constructing new water resources infrastructure, particularly to address the increasing hazards associated with climate change.

Water resources management (WRM) agencies, which are usually responsible for operating or regulating this infrastructure, need to develop sound economic and environmental policies and planning practices to guide new investments. Natural disasters often prompt reflexive calls for construction of new infrastructure which may be politically expedient, but decisions on long-lived and expensive infrastructure should be guided by high-quality economic and environmental analysis and by cost-sharing policies that encourage beneficiaries to help shoulder the burden. Since local governments are often responsible for operating water resources infrastructure, national governments can make their financial support contingent upon the adoption of non-structural risk reduction methods, such as floodplain management or water conservation.

Much of the existing stock of water resources infrastructure, including more than 58,000 large dams around the world, is aging. Some of dams are becoming unsafe, putting downstream communities at risk. In fact, dam failures have killed thousands of people around the world in recent decades and thousands of dams now are at risk of failure.[17] The WRM agency should lead national dam and flood embankment safety programs to help reduce these risks. Critical tasks include updating information about existing infrastructure, such as by identifying owners, revisiting safety regulations, and stepping up inspections and monitoring. It is also necessary to increase funding to upgrade or decommission existing facilities, or to build new ones.

Because of its long history of fighting floods, the Netherlands is one country that has made infrastructure investments a top priority. Its extensive system of dikes, storm surge barriers, canals, pumps, and water inlet facilities is maintained (and, where necessary, further developed) by 17 self-governing regional water boards and by the *Rijkswaterstaat*, a semi-autonomous agency within the Ministry of Infrastructure and Water Management. The Netherlands has also become increasingly sophisticated in integrating green infrastructure, such as maintaining floodplains and natural coastal barriers, to work in harmony with traditional gray infrastructure.

Ens, The Netherlands—Ramspol bridge and inflatable rubber dams on the river IJssel delta. Photo: © Sjoerd van der Wal.

7. Controlling Water Use and Floodplain Development

The C in the EPIC Response

Healthy watersheds and effective water resources infrastructure can reduce the severity of future flooding events and increase the availability of water during droughts. The next element in the EPIC Response Framework is about controlling or managing water and land resources to further reduce risks.

WRM agencies need to develop programs for flexibly and efficiently allocating water among users, particularly during periods of drought when competition for water is fierce and contested. A key water allocation strategy is to ensure that water supplies are not overallocated to allow for a buffer during droughts. Where groundwater is a significant water source, it is also important to have management programs that help preserve that water as a strategic reserve during droughts.

Developing an effective water allocation system is an extremely complex process, requiring large amounts of information and effective administrative control. Sustainably managing groundwater is even more challenging, as the basic physical parameters of aquifers are often poorly understood. More advanced countries have demonstrated, however, that water allocation systems are a key tool in their arsenal to use water efficiently and to respond to droughts. California has adopted the twin strategy of reducing water demands through municipal and agriculture water conservation, as well as embarking on a new groundwater management program. The state's 2014 Groundwater Act requires the formulation of sustainable groundwater management plans in 84 high priority aquifers, with a goal of achieving groundwater sustainability by 2040.

Governments also should seize the opportunity to better manage floodplains, which in many cases offers the most cost-effective approach to reducing flood risks. DRM agencies, working in collaboration with WRM agencies and local governments, can accomplish this through floodplain mapping, land use zoning, and building regulations, and by producing local flood mitigation plans. Controlling floodplain use, particularly in lower- and middle-income countries, is often constrained by lack of political authority or administrative capacity. Informal settlements, driven by rural-to-urban migrants, quickly spring up on unused land and relocation is often politically contentious and expensive. Influential property developers may be able to override floodplain regulations and develop their own flood-protected enclaves—shifting the floodwaters to other areas.

In many developing countries, floodplains are home to vulnerable informal settlements. In the Philippines, the Pasig River runs through densely populated Metro Manila on its way to Manila Bay. Over time, shanty towns filled with informal settlements sprang up on the river's banks and floodplains—and by the 1990s, the river was biologically dead and prone to deadly floods. Starting in 1999, the Pasig River Rehabilitation Commission was able to resettle 18,000 families to safer locations, create environmental preservation areas that serve to lower flood risks, and curb pollution.

Governments should seize the opportunity to better manage floodplains, which in many cases offers the most cost-effective approach to reducing flood risks.

8. Responding to Droughts and Floods

Farmers receive drinking water relief in rural areas of Tien Giang, Vietnam, during a severe drought. Photo: © Huy Thoai | Dreamstime.com

If a country has prepared well with effective EPIC programs, then the hydro-climatic risks should be significantly reduced. Nevertheless, there will always be some level of residual risk. The goal, therefore, is to effectively monitor, respond to, and recover from floods and droughts when they occur, and to minimize the final social, economic, and environmental impacts of those events. Particularly important are adequate and scalable safety nets that reduce the toll from extreme events and enable people to rebound more quickly from any damage.

Drought Response

Droughts are slowly evolving events that typically cover large geographic areas, and each drought has its own unique features. A country's National Drought Plan should provide a general roadmap for interagency coordination and response, and assess potential impacts and vulnerable populations before a drought strikes.

A comprehensive drought monitoring program, under the general auspices of the National Drought Committee, is essential for monitoring the evolution of the drought; this includes not only hydro-meteorological parameters, but also actual on-the-ground impacts and risks. In one example, Botswana, Eswatini, Zimbabwe, and other countries in Southern Africa are developing a composite drought index, which will lay the foundation for an improved drought management system. The strategy is to use satellite data, surface measurements, and computer models, along with on-the-ground assessments, to determine when actions should kick in to respond to dry spells.

Agriculture agencies should be prepared for weather-related extremes—whether they be floods or droughts, as part of a broader sector risk management strategy that considers a variety of potential risks, including climate risks, biological risks such as pests or disease, or economic dislocations. When an extreme hydro-climatic event does strike, the agriculture agency should be prepared to support vulnerable farmers and livestock producers with financial and other types of safety net support; in some countries, agricultural insurance may also be utilized.

Once droughts take hold, the WRM agency should oversee the activation of water resources-related drought contingency plans at the basin, city, and irrigation scheme levels. When droughts affect vulnerable populations, then pre-planned

and scalable social protection programs and other safety nets should be activated, such as food assistance or cash transfers. These drought response efforts need to be coordinated and monitored by the National Drought Committee—and when the drought has ended, there should be an assessment to understand final impacts, the effectiveness of response measures, and the lessons learned.

During drought years in the Netherlands, the government makes decisions on how to distribute the available water. The National Coordination Commission for Water Distribution, in which water managers at the national, provincial, and water board levels are represented, plays a key role in making water allocation decisions. There is a general pre-arranged priority system to try to minimize the impacts across a wide range of sectors, such as inland shipping (which suffers when canal and river water levels drop), agriculture, municipal water supplies, and natural ecosystems. Nevertheless, since each drought is unique, the Commission tailors the response to the specific conditions.

Flood Response

Relative to droughts, floods are more rapid onset disasters, which places a premium on accurate and timely forecasts. The national meteorological service is the primary source of the weather data that drive forecasts, but it needs to work closely with the WRM agency (or national hydrological service) for river flood forecasts. The DRM agency can provide an important value-added to the flood forecasts by spearheading a multi-purpose emergency warning system, alerting potentially affected people not only about the magnitude of the flooding but also about the potential impacts.

In California, the Department of Water Resources manages a flood control center to monitor and forecast floods; closely allied to the center are staff from the U.S. National Weather Service and the California Department of Emergency Services. These three agencies work together in an integrated manner to provide flood forecasts, warnings, and response.

Flood emergency preparedness is critical to an effective response. The DRM agency needs to work in collaboration with local governments and civil defense authorities to have multi-hazard emergency operation plans in place to respond to a variety of natural hazards, including floods. When a major flood does occur, the DRM agency will need to work closely with a wide variety of agencies and local governments to organize evacuations and ensure public safety. When there is extensive flood control infrastructure, the WRM agency plays a key role in flood operations and should be guided by the basin flood contingency plans discussed earlier.

Information on the actual flood impacts helps guide relief and recovery actions. The DRM agency should have standardized

Buildinmg a sandbag barrier to protect the city of Wittenberg, Germany, from the rising flood of the river Elbe. Photo: dpa picture alliance / Alamy Stock Photo.

procedures for organizing multi-disciplinary teams to assess impacts at different stages. A rapid impact assessment during or immediately after the flood is necessary to assess relief and rescue requirements. As soon as possible, the DRM agency should then organize a Post Disaster Needs Assessment (PDNA), which further defines relief needs and actions to restore critical infrastructure, protect public health, and develop an action plan for recovery. Input from the public, for example from social media, drone footage, or hastily organized survey teams of university students, can provide timely information on relief and recovery needs.

Heavy flooding in the Tanga Region of Tanzania in October 2019 caused loss of life, damaged and destroyed people's properties and critical infrastructure, and disrupted the provision of important services, such as transportation, education, and health. Tanzania's government, in partnership with international development agencies, undertook its first ever PDNA. The PDNA called for a recovery program valued at 150 percent more than the actual flood damages to allow affected areas to build back better and be more resilient in the future.

Recovering from floods offers an opportunity to help communities better prepare for the next flood. This is a complex and lengthy task that requires the DRM agency to take leadership in a joined-up government effort. DRM agencies can utilize disaster funding as an opportunity to work with local governments to improve floodplain management and help build back better. Flood insurance programs can also help provide funding for recovery efforts, but eligibility for policies should be made conditional on sound local floodplain management.

In November 2013, the Philippines was struck by Typhoon Yolanda (internationally known as Haiyan), one of the strongest storms ever recorded, with storm surges over four meters high. The typhoon caused storm surges that resulted in widespread flooding, which killed thousands of people and caused unprecedented damage. In the aftermath of the disaster, the Philippine government formulated the Yolanda Comprehensive Rehabilitation and Recovery Plan, which aims to improve the affected communities' physical, social, and economic resilience. A locally driven, nationally supported process was utilized to meet the unique needs of each community.

Disaster Risk Financing

The drought and flood response programs highlighted in this report depend on having adequate and timely funding, which can be a difficult challenge. The finance agency, working in collaboration with the DRM agency, should develop a national disaster financing strategy that corresponds with the country's disaster risk profile. Several possible approaches can be layered together to create an integrated portfolio, including national disaster funds, insurance programs, budget allocations, international aid, contingent disaster credit, and sovereign catastrophe bonds. Each of these instruments is ideally suited to a particular type of disaster, based upon the frequency and magnitude of the event. For example, national disaster funds are well suited for low impact and high frequency events, such as localized moderate flooding. For high impact and low frequency events, such as multi-year widespread droughts or catastrophic flooding associated with tropical cyclones, instruments such as contingent disaster credit or international aid (for low-income countries) can be utilized.

One innovation offered by the World Bank is development policy financing that incorporates a "catastrophe deferred drawdown option" (Cat DDO). The idea is to provide an immediate infusion of money to countries after a natural disaster or health emergency such as COVID-19. The funds are disbursed once a disaster is declared—thus offering immediate access to funding. World Bank approval of the financing is contingent upon the country adopting a set of policies to help mitigate risks and improve disaster response—precisely the type of interventions outlined in the EPIC Response Framework. Since 2008, the World Bank has approved 27 of these Cat DDOs, providing close to US$3.5 billion in 25 countries. About half of the money was triggered by floods and storms; the other half was in response to the COVID-19 pandemic.

One innovation offered by the World Bank is development policy financing that incorporates a "catastrophe deferred drawdown option" (Cat DDO). The idea is to provide an immediate infusion of money to countries after a natural disaster or health emergency such as COVID-19.

9. Overarching Recommendations for National Governments

Adopt an EPIC Response Framework approach that considers weather, watersheds, and water: A new approach is required to more effectively mitigate the hazards associated with extreme hydro-climatic events. This approach is embodied in the EPIC Response Framework, which use a hydro-climatic perspective to account for the interactions between weather, watersheds, and water. The role of weather in driving floods and droughts, and the importance of good meteorological and hydrological services, is obvious. As the climate changes and as extreme events become more frequent, governments must double down on improving these services and ensuring that they are useful for water and land use planning, drought monitoring, and flood forecasting.

Equally critical is sustainable land management within watersheds. Proper land management in terms of healthy forests, natural coastal defenses, climate-smart sustainable agriculture, and floodplain management can help reduce the impacts of extreme climatic events, whether it be long dry periods or intense storms. Governments need to think of floods and droughts not just as water problems, but rather as land and water problems. Finally, an integrated approach to water resources management is required to address both ends of the hydro-climatic spectrum. This implies water-related planning, investments, and management to mitigate both flood and drought hazards, as well contingency planning to make the best of bad situations when they strike.

Be prepared to respond when a flood or drought strikes: The EPIC programs will help to mitigate hazards, but there will always be residual risks. Governments, therefore, must also be prepared to respond to disasters and then help communities recover in a manner that enhances resilience. It will be a race against time; efforts to mitigate hazards may or may not keep pace with a changing climate. As a result, countries must make continuous improvements in their disaster risk management systems to reduce flood impacts and enable communities to build back better. Most governments also need to take quantum leaps forward in their abilities to monitor and respond to droughts. Governments will need to ensure adequate and scalable social safety nets

Planting 1000 mangrove seedlings in the village of Alue Naga, Banda Aceh. Photo: Pacific Press/Alamy Live News.

to respond to flood and drought events. Finally, the response, and especially the recovery programs, will need to depend on access to disaster risk financing using a broad portfolio of instruments that meet specific country risk profiles.

Promote a joined-up government approach through strategic planning: The EPIC Response Framework calls for thinking about hydro-climatic risks from a holistic perspective. Each of the program's areas are important and affect all other programs—generally, but not always, in a downward cascading manner. As demonstrated in the report, many agencies have specific mandates related to floods and droughts that they must perform effectively. However, this is not enough; the agencies also must understand their roles in the EPIC Response Framework and collaborate when required.

Such collaboration will require new forms of innovative governance in which no single agency has an exclusive role. Instead, the agencies must work together in a joined-up government approach. There are many challenges in implementing an effective EPIC Response Framework—generally a combination of political and economic constraints—and the implementation should be seen as an evolutionary journey, not a one-time event.

An important process for facilitating a dynamic and evolving joined-up approach is the periodic preparation, approximately every five years, of strategic national plans for WRM, DRM, and drought management. A strategic planning process should focus on reviewing sector performance and proposing adjustments to the policies, laws, interagency collaborations, programs, regulations, and funding to ensure continuous advancement. A national strategic plan does not necessarily mandate actions or make project-specific recommendations, but rather provides a general roadmap within which agencies need to continually adjust and fine tune their programs.

These strategic plans should be formulated through a multi-agency process with whole-of-society guidance. The WRM strategic plan should, of course, be led by the WRM agency, but it should also include the DRM agency in matters related to floods and droughts. In a similar manner, the DRM strategic plan needs to be led by the DRM agency, but the WRM agency should also actively participate in matters related to floods and droughts. The drought strategic plan requires the active involvement of the WRM, agriculture, and DRM agencies. Finally, the NMS/NHS needs to be intimately involved in all three strategic plans. National climate adaptation planning, often lead by the Environmental Agency, is also an overarching strategic planning process that can help advance a joined-up government approach to hydro-climatic risk management.

Periodic, interlocking strategic national plans for WRM, DRM, and Drought will help drive the evolution of climatic risk management in a country.

Rescue boats being transported to flooded areas of Kerala, India, badly affected by the floods during the monsoon season. Photo: © Ajijchan | Dreamstime.com.

10. Rising to the Challenge

The rapidly changing planet means that governments can no longer do business in ways that worked in past, using historical experience to guide future actions. As a result, there is a critical need for new, more flexible and adaptative approaches. And there is no time for delay.

The task ahead is daunting, and the global response needs to be epic. Climate change is here and potentially accelerating, with the period 2013-2020 being the hottest seven years on record. Climatic tipping points may lie ahead as ice sheets shrink and permafrost melts.[18] Already, the number of extreme "one-in-a-thousand year" events is soaring—in 2016, the United States alone had five deadly 1,000-year floods.[19]

But the key message of this report is that this is not an insurmountable challenge. The policy research and four case studies show we can march down the path towards more effective responses to the growing risks of floods and droughts. The hope is that the new knowledge and examples in the report will both inspire and guide more progress, enabling governments both to reduce the huge toll from hydro-climatic disasters—and to take advantage of the opportunities to create a more livable and prosperous planet.

Endnotes

[1] CRED (Centre for Research on the Epidemiology of Disasters) and UNDRR (United Nations Office for Disaster Risk Reduction). 2020. *The human cost of disasters: an overview of the last 20 years* (2000-2019). Brussels: CRED; Geneva: UNDRR.

[2] Risser, Mark D. 2017. "Attributable Human-Induced Changes in the Likelihood and Magnitude of the Observed Extreme Precipitation during Hurricane Harvey." *Geophysical Research Letter* 44 (24): 12,457-12,464.

[3] Gerretsen, Isabelle, and Jessie Yeung. 2019. "Europe's Heat Wave Is Shattering Temperature Records and Cities Are Struggling to Cope." *CNN*, July 25, 2019.
WWA (World Weather Attribution). 2019. "Human Contribution to Record-Breaking June 2019 Heatwave in France." WWA, July 2, 2019.
Mason, Charlotte. 2019. "European Farms, Wildlife Parched in Post-Heatwave Drought." *Phys.org*, July 16, 2019.

[4] GCA (Global Commission on Adaptation). 2019. *Adapt Now: A Global Call for Leadership on Climate Resilience*. Rotterdam: Global Center on Adaptation; Washington, DC: WRI (World Resources Institute).

[5] Howlett, Michael and M. Ramesh. 1995. *Studying Public Policy: Policy Cycles and Policy Subsystems*. Toronto University Press.

[6] Hammill, Anne, Jo-Ellen Parry, and Hayley Price-Kelly. "What the Paris Agreement Means for the National Adaptation Plan Process" 2016. *NAP Global Network* website.

[7] Kijazi, Agnes Lawrence, and C.J.C. Reason. 2009. "Analysis of the 1998 to 2005 Drought over the Northeastern Highlands of Tanzania." *Climate Research* 38 (3):209-223.

[8] Walsh, B. and S. Hallegatte. 2020. "Measuring Natural Risks in the Philippines: Socioeconomic Resilience and Wellbeing Losses." *EconDisCliCha* 4: 249–293.

[9] Thorne, James H., Joseph Wraithwall, and Guido Franco. 2018. *California's Changing Climate 2018: A Summary of Key Findings from California's Fourth Climate Change Assessment*. California Natural Resoruces Agency.

[10] Sanga, Camilius A. 2018. *e-Agriculture Promising Practice: UshauriKilimo.org: web and mobile phones for extension services in Tanzania*. Rome: FAO (Food and Agriculture Organization of the United Nations)

[11] Ritchie, Hannah and Max Roser. 2019, *Land Use*. Our World in Data.

[12] Food and Agriculture Organization (FAO). 2015. *Status of the World's Soil Resources*.

[13] Cook, Benjamin. 2019. *Droughts and Interdisciplinary Perspective*. Columbia University Press.

[14] Pingali, Prabhu L. 2012. "Green Revolution: Impacts, limits, and the path ahead." *PNAS* 109 (31): 12302-12308

[15] Ibid

[16] De Clercq, Matthieu, Anshu Vats, and Alvaro Biel. 2018. *Agriculture 4.0 the Future of Farming Technology*. World Government Summit.

[17] Lieb, David A., Michael Casey, and Michelle Minkoff. 2019. "AP: At Least 1,680 Dams across the US Pose Potential Risk." *AP News*, November 11, 2019.

[18] NASA (National Aeronautics and Space Administration). 2021. "2020 Tied for Warmest Year on Record, NASA Analysis Shows." NASA's Global Climate Change: *Vital Signs of the Planet*. January 12, 2021.

[19] Weaver, Scott. 2016. "We just had five 1,000-year floods in less than a year. What's going on?" EDF (Environmental Defense Fund) *Voices blog*, September 1, 2016.

All other factual informational cited in the Executive Summary is referenced in the Main Report

www.worldbank.org www.gfdrr.org www.worldbank.org www.deltares.nl