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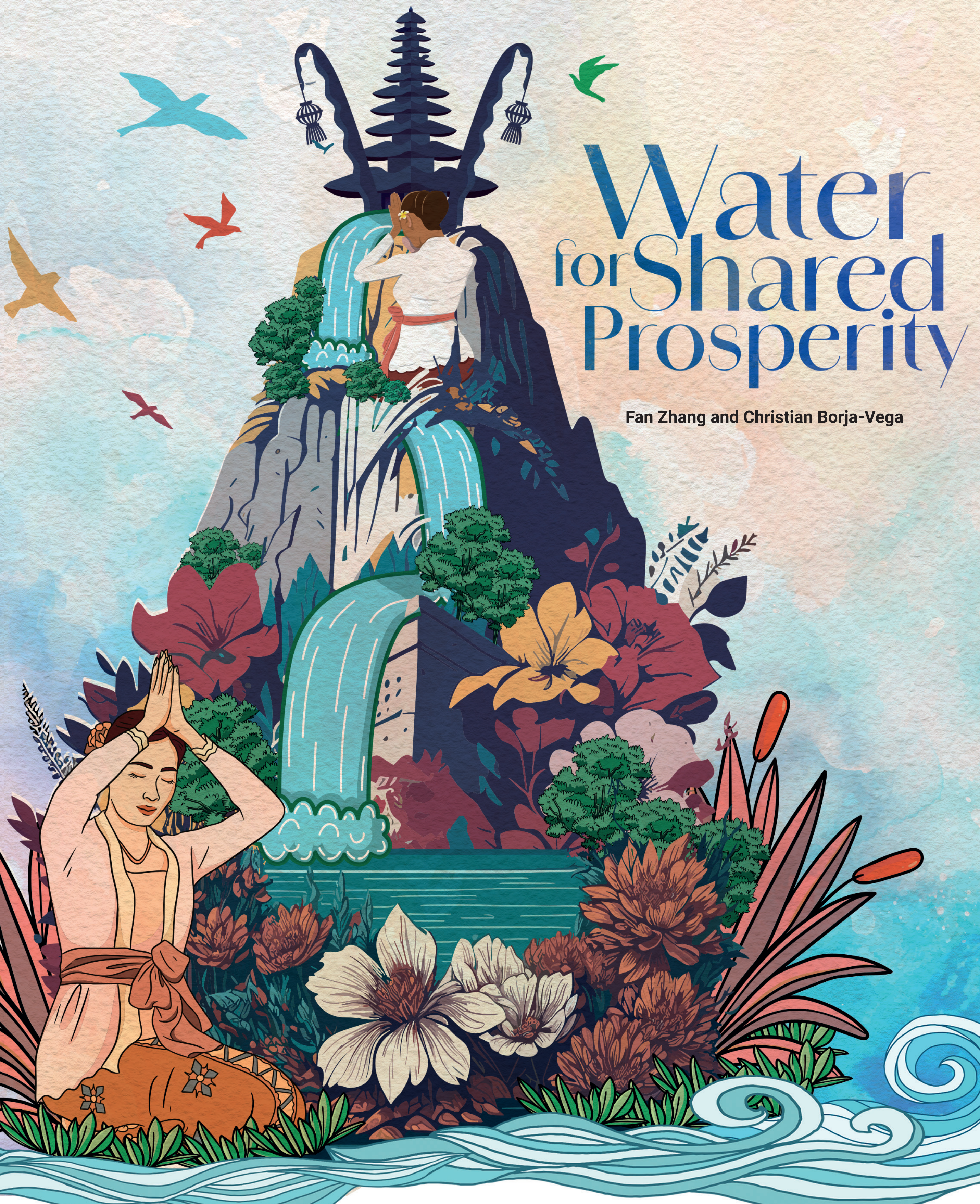
Water for Shared Prosperity

Fan Zhang and Christian Borja-Vega



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FOREWORD

I am very pleased to welcome this joint Indonesia–World Bank publication "Water for Shared Prosperity," which is the main theme of the 10th World Water Forum that will be hosted by Indonesia from May 18 to 25, 2024. Indonesia has made strong progress in economic growth and poverty reduction over the past decade. Average gross domestic product (GDP) per capita increased almost ninefold in real terms since 1950, driving the expansion of its middle class and significantly reducing poverty. Indonesia's economy rebounded after COVID-19 with five percent GDP growth, and projections suggest continued growth of 5.2 percent through 2025.

The "Indonesia Vision 2045" sets out an ambitious target to further accelerate growth and transform the country into the fifth largest economy in the world, which will require an average real GDP growth rate of 5.7 percent until 2045, 100 years after Independence. A joint Bappenas–World Bank study "Indonesia Vision 2045: Towards Water Security," found that without dedicated action on water security, the country will fall short of its 2045 GDP target by up to 7.3 percent and recommends action in three main pillars covering: (i) water threats; (ii) water services; and (iii) water governance.

Climate change poses a serious threat to economic growth and shared prosperity, and Indonesia is particularly affected. Increasing volatility of rainfall and runoff magnifies flooding and droughts. Sea level rise is jeopardizing Indonesia's many and densely populated lowland areas. By 2050, 31 percent of Indonesia's districts will no longer record months of surplus water, more than double the number in 2010. More erratic rainfall patterns are compounded by a lagging national water storage capacity. About 50 percent of Indonesia's GDP is currently produced in river basins experiencing "severe" or "high" stress in the dry season.

This report addresses the 10th World Water Forum's main theme "Water for Shared Prosperity" by looking at the water challenges and risks that pose a threat to sustainable and inclusive development and economic growth, and by recommending concrete action to improve the access to water and strengthen climate resilience, while lifting all boats at the same time. The report showcases the many Indonesian innovations that have been successful in addressing water insecurity and promote shared prosperity. Small-scale desalination plants have been instrumental in providing potable water to communities living on small islands and can be managed by these communities to ensure sustainability. To adapt to the impacts of climate change, the Government of Indonesia is investing in the development of 61 dams that can store 3.81 billion cubic meters of water to reduce flooding and increase water supply for people, agriculture, and environment.

In many of these reservoirs, investments can be made in tourism, hydropower, floating solar and fresh-water fisheries to generate multi-purpose revenues that can help pay for the operation and maintenance of the dams and the associated irrigation systems. Improving the safety of Indonesia's 250 small and large dams, as pursued under the Dam Operational Improvement and Safety Project, helps improve dam operations so they can play a more effective role in reducing floods and increasing water supply.

Comprehensive river restoration through the Citarum Bersih program in Java's largest river helps address water insecurity that is the result of pollution. The lessons learned can be used to scale up the experience in Indonesia and elsewhere. Bali's Subaks demonstrate the important role that communities play in the management of irrigation and showcases the sustainability of these century-old institutions. Communities can also play an important role in disaster risks management by managing and operating early warning systems. Lastly, Indonesia's Rural and Urban Water Supply Projects (PAMSIMAS and NUWSP) show that sustainable and financially viable water supply can be achieved through community involvement and by providing appropriate incentives to Local Governments and water utilities to improve the quality of service delivery.

I genuinely hope that this report will help inspire countries and galvanize communities across the world and infer a sense of pride to Indonesia as it is sharing with the world its solutions to water security and shared prosperity.

H.E. Pak Basuki Hadimuljono
Minister of Public Works and Public Housing, Republic of Indonesia

FOREWORD

I am pleased to present this book on Water for Shared Prosperity which makes a compelling case that the World Bank's vision of a world free of poverty on a livable planet will depend on achieving water security for all. The focus on the connection between water, economic growth and shared prosperity is a distinctive contribution of this book. Three aspects are highlighted as particularly important for human and economic development–access to safe drinking water and sanitation, the availability of water as an input to economic activities, and the management of increasing hydro-climatic extremes, notably droughts and floods.

The essential role of water in human activity and the environment means that it impacts development at grand-scale. Water shortages–or floods–can have devasting, economy-wide effects: Agriculture, fisheries, energy production, manufacturing and transportation all depend significantly on secure and well-managed water services. In low-income countries, nearly 60 percent of the population works in agriculture and hydroelectric power alone generates some 40 percent of electricity on average.

Water also has outsized impacts on human wellbeing and the labor force: Polluted water and poor sanitation and hygiene are causing at least 1.4 million deaths per year globally. Water-related diseases like malaria add up to such death toll and so does chemical contamination of water, including lead and arsenic. Exposure to chemicals and bacteria in water undermine the long-term physical and cognitive development of tens-of-millions of children. The need to fetch water from faraway sources limits time for school and productive work across developing countries, especially for girls and women. As the evidence presented in this book also shows, the poorest segments of the population are typically most exposed to water-related risks.

Over the past decades, the water resources and infrastructure needed for healthy populations and functional economies have come under increasing stress. Rapid demographic expansion, economic growth, pollution and inefficient resource management have led to the disappearance of 30 percent of natural freshwater ecosystems over the past 50 years. Nearly a third of the world's regional aquifers show not just a decline but an accelerating depletion. Climate change will further accentuate these pressures.

What is to be done? In the pages that follow, decision-makers will find valuable insights and policy recommendations for a more sustainable, efficient, and equitable management of global water resources, as well as concrete examples of how Indonesia, the host of the 2024 World Water Forum, is applying them in practice. Significant reforms and investments are needed to improve resilience to climatic extremes, and to strengthen the value chain of water services from source to distribution. This will require major new infrastructure, the introduction of early-warning systems and more accessible insurance against floods and droughts, regulatory reforms to achieve a more efficient allocation, management and pricing of water services while protecting the poor, and closer cooperation in managing transboundary water.

The World Bank is ready to play a key role and has identified fast-tracking water security and climate adaptation as an operational priority. In the East Asia Pacific region, we have already committed over $10.8 billion to finance water-related projects and reforms over the past decade. However, aggregate financing shortfalls to achieve global water security are estimated to amount to trillions of US dollars. This is more than government and international financial institutions such as the World Bank can finance on their own.

The private sector will thus play an important role in solving global water challenges within a regulatory framework that protects public resources and the most vulnerable.

“Water for Shared Prosperity” is a call to action and useful source of evidence and policy guidance to address these challenges and improve our collective stewardship of our planet’s most essential resource–water.

Manuela V. Ferro
World Bank Vice President for East Asia and the Pacific

PREFACE

I am honored to present the joint Indonesia–World Bank publication, "Water for Shared Prosperity," which resonates deeply with the sentiments expressed by both Minister Basuki of Indonesia and Manuela Ferro, the World Bank Vice-President for East Asia and the Pacific.

Minister Basuki's endorsement underscores Indonesia's commitment to addressing water challenges as a cornerstone of its development agenda. The country's ambitious growth targets outlined in the "Indonesia Vision 2045" underscore the critical importance of water security in achieving sustained prosperity. The joint Bappenas–World Bank study further highlights the imperative of action in mitigating water threats, enhancing water services, and bolstering water governance to ensure resilient growth.

Similarly, the Vice President's foreword underlines the urgent need for collaborative action placing water challenges and solutions at the forefront of the development agenda, to address global challenges such as poverty, inequality, and climate change. The World Bank's commitment to scaling up investments and strengthening partnerships, to steer the road of shared prosperity, aligns seamlessly with the objectives of this publication.

By showcasing the water sector's global trends and challenges and presenting successful cases around the world, our task to promote water security demands the highest standards. As we also learn from the Indonesian innovations in addressing water insecurity and promoting inclusive growth, this report offers new ways of promoting policies and accessible solutions. From small-scale sanitation systems to comprehensive river restoration programs, Indonesia's initiatives demonstrate the transformative power of community involvement, inclusivity, and sustainable practices.

As we navigate the complexities of a post-pandemic world and confront the existential threat of climate change, this publication serves as a beacon of optimism and action. It offers actionable recommendations to enhance water accessibility, strengthen climate resilience, and alleviate poverty, while fostering collaboration and driving meaningful change on a global scale that prioritizes the poorest.

I extend my heartfelt gratitude to all contributors, partners, and stakeholders whose dedication and expertise have made this publication possible. May "Water for Shared Prosperity" inspire renewed commitment and collective action towards a future where water serves as a catalyst for shared prosperity on a livable planet.

Saroj Kumar Jha
Global Director for Water
World Bank Water Global Practice

EXECUTIVE SUMMARY

In 1997, thousands of people gathered in Marrakesh, Morocco, for the first World Water Forum to address an urgent problem: the global water crisis. The meeting resulted in the Marrakech Declaration, a pledge that called on the World Water Council to develop a "World Water Vision" for the 21st century. In 2024, thousands are convening in Bali, Indonesia, for the 10th World Water Forum. They will be addressing the same crisis. But if the water crisis was already acute nearly three decades ago, its urgency has become even greater today. Population and economic growth, coupled with environmental degradation and climate change, have greatly intensified the global water crisis, as the Republic of Indonesia's President Ir. Joko Widodo has remarked (World Water Forum 2024).

Indonesia and Morocco are worlds apart in many ways. As the world's largest archipelago, Indonesia is surrounded by water. On the other hand, Morocco is partly occupied by the Sahara, the world's largest hot desert. However, one reality these (and many other) countries share is water stress. The 10th World Water Forum is an invitation to consider the collective water issues in countries as different as Indonesia and Morocco and to draw parallels among them. But it is also about finding solutions. These solutions must work for rural farmers and urban dwellers across the world. They must stimulate economic growth, but they cannot end there. They must also improve the lives of the poor and marginalized, consider inclusive infrastructure, and tackle climate change. These tasks require inclusive actions, and hence the idea of water for shared prosperity, the theme of the 10th World Water Forum.

In that vein, "Water for Shared Prosperity," the global flagship report of the 10th World Water Forum co-published by the World Bank and the Government of Indonesia, aims to identify the water challenges and risks faced by the poorest and most marginalized populations and to inform policies that enhance water accessibility and climate resilience while alleviating poverty and boosting shared prosperity. Although various reports have covered water and development, this one fills a knowledge gap by exploring the connection between water and inclusive growth.

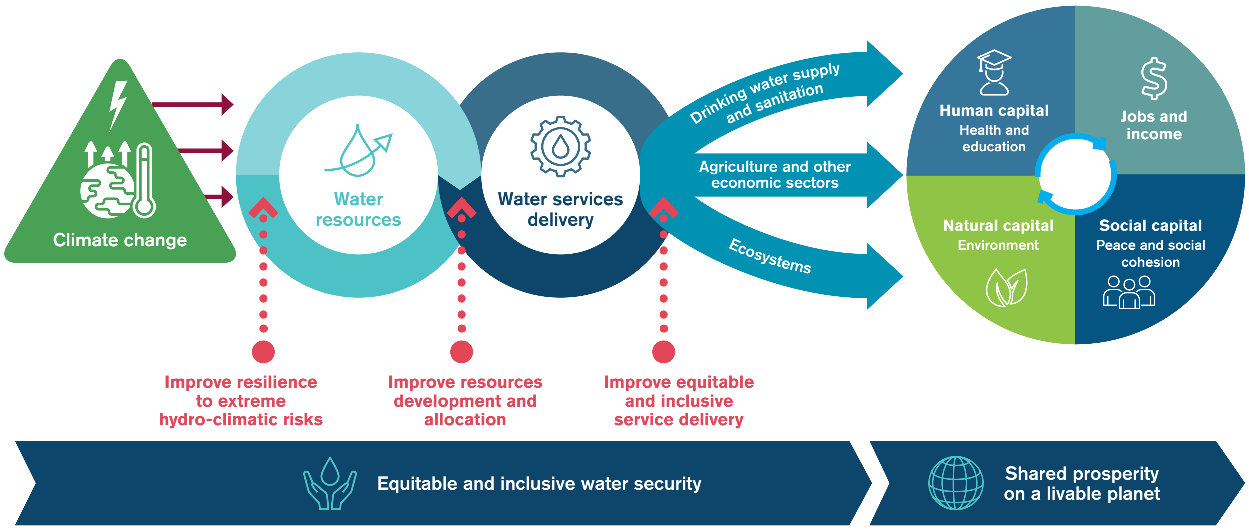
This report makes three major contributions. It (1) provides a conceptual framework to illustrate the relationship between water and shared prosperity; (2) presents new empirical evidence on the drivers, extent and costs of inequalities in water access, as well as disparities in the impacts of climate-related water shocks; and (3) identifies policy responses to improve water access, strengthen climate resilience, and promote shared prosperity on a livable planet.

WHY WATER MATTERS FOR SHARED PROSPERITY: A CONCEPTUAL FRAMEWORK

Prosperity is multidimensional. This report defines four interconnected building blocks of prosperity: health and education (human capital), jobs and income, peace and social cohesion (social capital), and the environment (natural capital). Water determines prosperity through three primary channels: as safe drinking water, as an essential input for various economic sectors, and as a critical support for ecosystems (Figure ES.1).

Heath and Education. Water is at the core of equality of opportunity for health and education. Numerous studies have established the causal link between safe and reliable water supply and various aspects of

FIGURE ES.1 Equitable and inclusive water security for shared prosperity on a livable planet



Source: World Bank.
Note: Water security is defined as the availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems, and production, coupled with an acceptable level of water-related risks to people, environments, and economies (Grey and Sadoff 2007). Water services include irrigation, water supply, and sanitation.

health (Andres et al. 2018; Maccini and Yang 2009; Shah and Steinberg 2017). Remarkably, through its impact on human capital accumulation, the effects of access to water resources and water services, particularly during the early stages of life, are long-lasting, often spanning multiple generations for vulnerable individuals and communities. For instance, a dry shock in infancy can trap subsequent generations in poverty and malnutrition (Damania et al. 2017). Children who grew up in homes with access to basic services like running water and sanitation are not only more likely to achieve a better education themselves but also tend to have children who attain higher levels of education (Gould, Lavy, and Paserman 2011).

Jobs and Income. Water is also an essential input in production, and its reliable supply has a significant impact on economic growth, jobs creation, and wages (Mueller and Quisumbing 2011; Mahajan 2017; Khan et al. Forthcoming). In developing countries, where farming and fishery are often the main livelihoods, employment disproportionately relies on water-intensive sectors and is sensitive to water availability. Water-intensive sectors are responsible for 56 percent of jobs in low-income countries and only 20 percent in high-income countries. In Sub-Saharan Africa, where water-dependent jobs account for 62 percent of total employment, low rainfall availability often leads to large negative GDP growth (Miguel, Satyanath, and Sergenti 2004; Petherick 2012).

Peace and Social Cohesion. The management and distribution of shared water resources can affect social cohesion and the risk of conflicts at local, national, and transboundary levels. If water resources are managed effectively and equitably, they can foster trust, inclusivity, and cooperation among communities, ultimately promoting peace. However, if mismanaged, water can act as a threat multiplier, exacerbating existing conflicts or leading to new conflicts. Countries with large populations, political exclusion of ethnic groups, and a low level of human development are usually more susceptible to civil unrest that can be triggered by water supply disruptions (Ide et al. 2020).

Environment. Water provides a habitat for aquatic life, fosters biodiversity, and allows nutrient transport within and among ecosystems. Water acts as a coolant to regulate temperature and influences or even defines weather and climate patterns. It creates landscapes through erosion and sedimentation. In short, water sustains life, fosters biodiversity, and makes our uniquely blue planet livable.

INEQUALITIES IN WATER ACCESS THREATEN BROAD-BASED DEVELOPMENT

Water is a crucial source of prosperity, but realizing its benefits requires sustainable management and development of water resources, along with equitable and inclusive delivery of water services. However, disparities in access to water resources and services are widespread. These challenges, further compounded by population growth, rapid urbanization, and climate change, pose a significant threat to shared prosperity.

By 2100, Africa's per capita freshwater resources are projected to be 64 percent lower than today. In contrast, Europe's are projected to be 0.4 percent higher. Low-income countries are also affected by higher seasonal rainfall variability, compounding their challenges in accessing reliable water sources. Globally, in 2022, 2.2 billion people lacked access to safely managed drinking water services; 3.5 billion people lacked access to safely managed sanitation (WHO/UNICEF JMP 2023); 1.7 billion people lacked basic water services at their health care facility (WHO/UNICEF 2022a); and close to 550 million children attended schools without basic water and sanitation services (WHO/UNICEF 2022b).

Although significant disparities in access to safely managed water and sanitation also persist in high-income countries (Mattos et al. 2021), the challenges are more formidable for low-income and least-developed nations. Countries with higher percentages of individuals living in extreme poverty also have higher percentages of people living without access to at least basic water and sanitation services. Despite an increase in global coverage, the access gap between the rich and poor remains large. In low-income countries, access has even regressed: in 2022, an additional 197 million people lacked safe drinking water, and 211 million lacked basic sanitation, compared with the year 2000. Eight out of 10 people who lack access to at least basic drinking water services and 7 out of 10 without access to at least basic sanitation services live in rural areas, and little progress has been made in closing the rural-urban access gap in low-income countries over the past two decades.

Unsafe water is a leading contributor to child mortality (Kremer et al. 2024). At the global level, during 2019 alone, poor WASH conditions contributed to between 1.4 and 4.2 million deaths and between 74 million and 204 million disability-adjusted life years (DALYs) due to diarrhea, acute respiratory infections, undernutrition, and soil-transmitted helminthiases (WHO 2023). Lack of access to WASH also affects optimal cognitive development, school attainment, labor productivity, and income.

Also evident are disparities in access to irrigation. Although irrigation expansion over the past 75 years has transformed the global agricultural landscape, the benefits of irrigation have yet to be equally shared. Gender, land distribution, class status, and access to capital all play a role in determining the distribution of benefits within irrigation systems. Differential impacts can even be felt between continents—African rice farmers benefit little from irrigation and related seed development, but they must compete with low-cost rice produced from irrigated Asian farms.

CLIMATE CHANGE CAN EXACERBATE POVERTY AND INEQUALITY

Climate change manifests itself mainly through its impact on the water cycle. As global temperatures rise, water supply will become more unpredictable, droughts will increase in frequency and severity, and disease outbreaks after floods will become more likely (IPCC 2023). These water shocks can lead to crop damage, lower food supplies and income, higher food prices, and increased risk of waterborne disease. Water shocks also threaten peace and stability. Rainfall anomalies are shown to be associated with increased incidences of conflict and social unrest, particularly in countries where rainfed agriculture is the dominant source of income (Raleigh, Linke, and Dowd 2012; Hsiang, Burke, and Miguel 2013; Sarsons 2015; Koubi et al. 2021).

Developing countries and poor households are most exposed to climate shocks. During the period between 2000 and 2021, developing countries have been disproportionately affected by droughts, experiencing more widespread and severe episodes compared to developed countries. Developing countries are also more susceptible to flood-related risks and have endured longer-lasting floods during the same period. Within countries, in urban areas, the poor are disproportionately at risk from flooding (Hallegatte 2016). Low-cost housing in flood-risk areas is more affordable for the poor than other options (Zhang 2016). Despite the perceived riskiness of flood-prone areas, socioeconomic factors often force the poor to settle in these areas.

Climate shocks can have significant and long-lasting impacts on vulnerable households. The poor are systematically underinsured. Uninsured or partially insured climate risks can increase risk aversion and can shift income-maximizing investment to risk-reducing investment or discourage it altogether (Amare and Shiferaw 2017; Di Falco and Chavas 2009). For example, farmers are likelier to stop using fertilizer, leading to lower income growth in the long term (Dercon and Christiaensen 2011).

Droughts and floods can also lead to disinvestment in human capital development, with school dropout rates increasing as a coping strategy to deal with financial hardships caused by water shocks. Extreme floods can also affect school attendance by disrupting physical access to school facilities. The current report estimates that extreme-flood-induced school absenteeism during 2000–22 will result in a lifetime earnings loss of $565 billion for affected school children at the global level, with those in low-income countries being particularly affected. The interconnected and cumulative impacts of climate shocks on income and human capital could cause an additional 68 million to 135 million people to fall into poverty by 2030 (Afino et al. 2020).

POLICY RECOMMENDATIONS: THE WAY FORWARD

When water resources, infrastructure, and services are not adequately managed, developed, and delivered, water-related challenges—issues with too much, too little, or too polluted water—can exacerbate inequalities and fragility. Throughout the value chain of water supply, from source to distribution, three types of interventions can significantly improve water security and, concurrently, reduce poverty and increase shared prosperity. These interventions aim to achieve (1) resilience to extreme hydro-climatic risks, (2) water resources development and coordinated allocation to different water uses, and (3) equitable and inclusive delivery of water services.

Achieving these three policy objectives requires a comprehensive set of interventions. This report outlines the following policy recommendations that policy makers can consider to achieve equitable and inclusive water security.

- Enhancing resilience to extreme hydro-climatic risks for the poorest by
  - Setting up robust and inclusive early-warning systems.
  - Developing insurance programs for weather risks and mitigating exposure to hydro-climatic risks through regulations and financial support.
  - Scaling up social protection schemes to assist vulnerable communities impacted by floods, droughts, or both.

- Improving water resources development, management, and allocation by
  - Scaling up nature-based solutions through innovative financing schemes and evidence-based approaches.
  - Enabling coordination of and cooperation for water allocation through information sharing and financial incentives.
  - Adopting water accounting to inform water allocation decisions.

- Improving equitable and inclusive service delivery by
  - Scaling up financing through institutional and tariff reforms.
  - Establishing participatory water governance to ensure transparency and accountability.
  - Creating an enabling regulatory and policy environment to promote innovations.
  - Improving coordination of institutions responsible for water, health, education, and urban planning.

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ABBREVIATIONS

AED	atmospheric evaporative demand
BAPPENAS	Ministry of National Development Planning (Indonesia)
BMI	body mass index
BMKG	Meteorological, Climatological, and Geophysical Agency
BUMDES	Village-Owned Enterprises (Indonesia)
CAP	community action plan
CDD	community-driven development
CEDLAS	Center for Distributional, Labor and Social Studies
CEQ	Council on Environmental Quality of the White House
CIESIN	Center for International Earth Science Information Network
CMIP6	Coupled Model Intercomparison Project Phase 6
CSR	corporate social responsibility
DALY	disability-adjusted life year
DFO	Dartmouth Flood Observatory
DHS	Demographic and Health Survey
D-INDEX	Dissimilarity Index of the Human Opportunity Index
DOISP	Dam Operational Improvement and Safety Project
FAO	Food and Agriculture Organization of the United Nations
FTWSCA	Fast Track Water Security and Climate Adaptation
GBD	Global Burden of Disease
GCP	Global Challenge Program
GDP	gross domestic product
GPP	Geospatial Poverty Portal
GSAP	Global Subnational Atlas of Poverty
GWSP	Global Water Security and Sanitation Partnership
HDI	Human Development Index
HFNF	Hollow Fiber Nano Filtration
HLO	Harmonized Learning Outcomes
HOI	Human Opportunity Index
HWISE	Household Water Insecurity Experiences
IBGE	Brazilian Institute of Geography and Statistics
IDR	Indonesian rupiah
IPCC	Intergovernmental Panel on Climate Change
IHE-Delft	Institute of Hydraulics and Environmental Engineering
IHME	Institute of Health Metrics and Evaluation
IMF	International Monetary Fund
IPUMS	Integrated Public Use Microdata Series
IWISE	Individual Water Insecurity Experiences Survey
JMP	Joint Monitoring Programme (WHO/UNICEF)
LAYS	Learning Adjusted Years of Schooling

LIC	low-income country
LMIC	lower-middle income country
LSMS	Living Standards Measurement Study
MICS	Multiple Indicator Cluster Surveys
MPWH (PUPR)	Ministry of Public Works and Housing (Indonesia)
NASA	National Aeronautics and Space Administration
NUWSP	National Urban Water Supply Project
OECD	Organization for Economic Co-operation and Development
PAMSIMAS	National Rural Community Water and Sanitation Project
PES	payment for environmental services
PPP	purchasing power parity
PTMOYA	Moya Holdings Asia Limited (Indonesia)
RCP	Representative Concentration Pathway
SDG	Sustainable Development Goal
SEDLAC	Socio-Economic Database Latin America and Caribbean
SPEI	Standardized Precipitation Evapotranspiration Index
SWRO	seawater reverse osmosis
UMIC	upper-middle income country
UN	United Nations
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNEP-DHI	Centre on Water and Environment of the United Nations
UNICEF	United Nations Children's Fund
WASH	water supply, sanitation, and hygiene
WBES	World Bank Enterprise Survey
WEF	World Economic Forum
WHO	World Health Organization
WMO	World Meteorological Organization
WRG2030	Water Resources Group 2030
WRI	World Resources Institute
WRM	water resources management
WSS	water supply and sanitation
WWC	World Water Council

All dollar amounts are U.S. dollars unless otherwise indicated.

Overview

CHAPTER 1

“We forget that the water cycle and the life cycle are one.”

Jacques Yves Cousteau

ABOUT THE TENTH WORLD WATER FORUM

When the first World Water Forum was held in 1997, the world was already facing a global water crisis. The forum, which took place in Marrakech, Morocco brought together 400 attendees to address this crisis. Thus, was born the Marrakech Declaration, which directed the World Water Council to develop the "World Water Vision" for the 21st century. Nearly three decades later, in 2024, hundreds are convening for the 10th World Water Forum in Bali, Indonesia, to address the same crisis. But this time the crisis has become more alarming. The President of the Republic of Indonesia H.E. Ir. Joko Widodo remarked that population and industrial growth, coupled with environmental degradation and climate change, have greatly intensified the global water crisis (World Water Forum 2024).

Indonesia and Morocco are worlds apart in many ways. As the world's largest archipelago, the former is surrounded by water. Conversely, although the latter has a coastline, a considerable portion of its landmass is in the Sahara, the world's largest hot desert. Water stress touches not only many facets of life in Indonesia and Morocco, but also in many other countries worldwide. The 10th World Water Forum is an invitation to consider the collective water issues in countries as different as Indonesia and Morocco and to draw parallels between them. But it is also about finding solutions. These solutions must work for rural farmers from Bangladesh to Kenya and urban dwellers from Brazil to Spain; they must work for poor and marginalized groups and stimulate economic growth. Moreover, they must consider inclusive infrastructure as they tackle climate change. More in general, inclusive action is required—hence the idea of water for shared prosperity, the 10th World Water Forum theme.

WHAT IS SHARED PROSPERITY?

A decade ago, the World Bank introduced twin goals: to end extreme poverty by reducing the number of people living on less than $1.25 a day to 3 percent by 2030 and to promote shared prosperity by fostering income growth for the poorest 40 percent of the population in every developing country (World Bank 2014).[1] Since it is arguably impossible to achieve the first goal without considering the second and vice versa it stands to reason that shared prosperity is prosperity that lifts all boats, development that lifts even the most marginalized members of society.

The World Bank has updated its definition of shared prosperity to "boosting prosperity, particularly for the poorest, to achieve more equitable societies" (Development Committee 2023). It has also updated its vision and mission to reflect the climate crisis and other global challenges. Its new vision is to create a world free of poverty on a livable planet, and its new mission is to end extreme poverty and boost shared prosperity on a livable planet (Development Committee 2023).

Shared prosperity goes beyond income and wealth. It is underpinned by a society that provides equal opportunities for all to thrive. Indeed, the issue of inclusion is at the heart of the World Bank's agenda to boost shared prosperity (World Bank 2014). As is acknowledged in the World Bank's mission statement, inclusion means "increasing and improving the distribution of opportunities, resources, and choices for all, especially for women, youth, as well as vulnerable and marginalized people, with special focus on human development (including education, health, and social protection)" (Development Committee 2023). The linkage here, as this report will detail, is that any water solutions should be inclusive solutions that benefit all segments of the population and involve them in the development process of a livable planet.

FOCUS OF THIS REPORT

This report addresses the 10th World Water Forum's theme, "Water for Shared Prosperity." It focuses on distributional analysis by identifying water challenges and risks faced by the poorest and most marginalized population. Its purpose is to inform policies and investment decisions aimed at enhancing water access, strengthening climate resilience, and concurrently alleviating poverty and boosting shared prosperity. Although many reports have covered water and development, this report fills a knowledge gap by exploring the intricate connection between water and inclusive growth.

This report makes the following three contributions. It (1) provides a conceptual framework to illustrate the relationship between water and shared prosperity; (2) explores and presents new empirical evidence on the drivers, extent, and hotspots of inequalities in access to water services and disparities in exposure to and impact of climate-related water shocks; and (3) identifies policy responses aimed at addressing disparities in water access and impact of water shocks to promote shared prosperity. It incorporates a comprehensive review of related literature and builds on the World Bank's previous work on water, economy and climate change, water poverty diagnostics and water social inclusion analysis. It also introduces fresh new empirical analysis to offer a deeper understanding of the topic.

As detailed in the next section, the report is based on a conceptual framework that recognizes water's role in creating better economic outcomes and providing equal economic opportunities for all segments of society. The former includes jobs and income. The latter comprise health and education, the two foundational elements required to level the playing field and eliminate barriers to social mobility and inclusion (De Ferranti 2004; De Barros 2009). The report also delves into the significance of water in promoting peace, social cohesion, and a healthy environment—all of which are crucial components of prosperity that directly impact economic outcomes and opportunities. This report therefore argues that inequalities in access to water resources and water services as well as disparities in exposure and vulnerability to water shocks pose a direct threat to shared prosperity.

The report discusses water-related inequalities along two primary dimensions: (1) the disparity across countries, particularly between high-income and low-income countries, and (2) the disparity between the well-off and the poorest individuals within a country.[2] In addition to disparities based on income, the report highlights evidence of unequal access to water services among marginalized groups due to factors such as gender, location, ethnicity, race, political beliefs, and other social identities. These identities often "intersect"—the effects of multiple forms of discrimination combine, overlap, or reinforce each other—a concept known as intersectionality, and the excluded groups are frequently overrepresented among impoverished communities (Das, Fisiy, and Kyte 2013).

WHY WATER MATTERS FOR SHARED PROSPERITY

Like poverty, prosperity is multi-dimensional (World Bank 2018). Although often defined according to income, it also encompasses non-monetary factors, such as health, nutrition, access to education, a peaceful society, and a healthy and sustainable environment. In the framework presented below, the report defines four interconnected building blocks of prosperity and three primary channels through which water determines prosperity. The report then describes how challenges related to access to water services and hydro-climate shocks disproportionately affect poor and vulnerable populations. Finally, the report highlights three key points in the value chain of water supply where effective policy interventions could mitigate the impact of climate change and promote equitable and inclusive water services delivery. By addressing the water challenges facing the poorest and most marginalized population, societies are more likely to achieve shared prosperity on a livable planet (Figure 1.1).

FOUR BUILDING BLOCKS OF PROSPERITY

The report outlines four fundamental building blocks that contribute to society's shared prosperity: human capital, social capital, natural capital, and jobs and income. More specifically, human capital refers to health and education, social capital stands for peace and social cohesion, and natural capital refers to the environment. The four building blocks are closely linked and mutually reinforce each other, as explained in the following.

Human capital: Health and education

Health and education determine future economic opportunities. Philosophers and economists have long argued that equality of opportunity is critical to achieving distributive justice (Arneson 1989; Cohen 1989; Dworkin 1981a,b; Roemer 1998; Rama et al. 2015; Van De Gaer and Ramos 2020). The idea is that personal talent and efforts—rather than circumstances at birth, such as gender, location, and race—should determine an individual's prospects of success in life. Health and education are at the core of equality of opportunity. Children with better health and education are better equipped to reach their full potential and live productive lives. Societies with higher equality of opportunity are more likely to achieve broadly distributed growth. Moreover, by increasing labor productivity, improvements in health and education outcomes can result in better job opportunities and higher income.

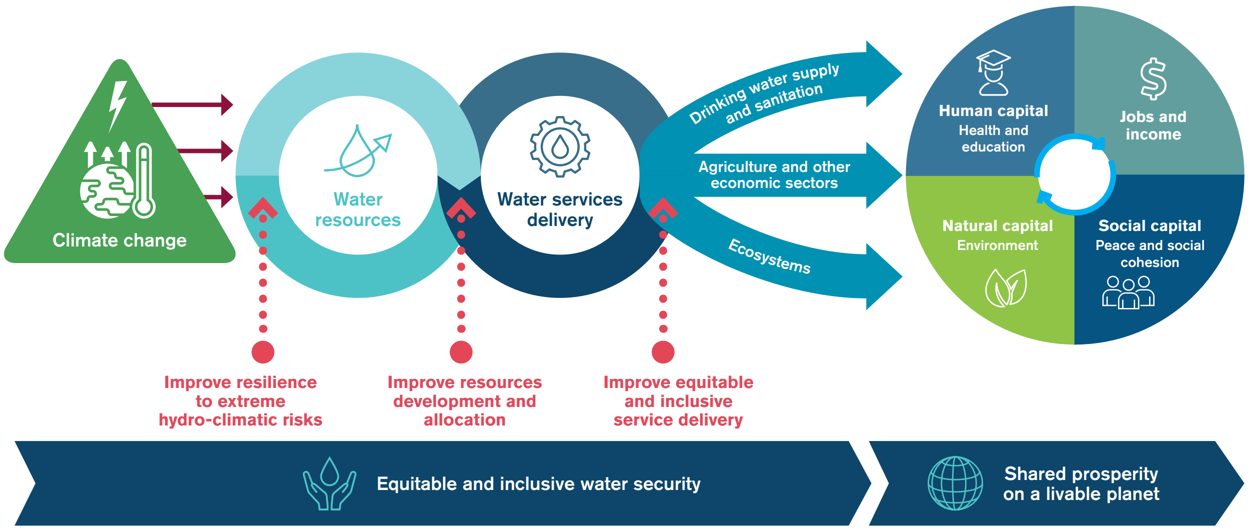
Jobs and income

Jobs are an important, if not the most important, metric for measuring current economic outcomes. Countries with higher employment levels tend to have lower poverty rates (Beegle, Hentschel and Rama, 2013). According to Acemoglu (2019), shared prosperity cannot be achieved solely through redistribution; it is created by generating jobs with decent incomes. Better jobs and higher incomes also enable families to invest more in human capital, resulting in improved health and education outcomes for their children. Societies with robust labor markets are likelier to achieve greater social cohesion and political stability. On the other hand, human, social and natural capital all play an important role in generating higher income.

Social capital: Peace and social cohesion

Peace and social cohesion among individuals and social groups are essential for achieving shared prosperity within societies and among nations. Peace provides the foundation for economic growth, infrastructure development, human capital investment and efficient resource allocation. Conflicts on the other hand can disrupt economic activity, devastate human and physical capital, and exacerbate inequalities. They also have the potential to spill over borders and cause regional or even global instability.

FIGURE 1.1 Equitable and inclusive water security for shared prosperity on a livable planet



Source: World Bank.
Note: Water security is defined as the availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems, and production, coupled with an acceptable level of water-related risks to people, environments and economies (Grey and Sadoff 2007). Water services include irrigation, water supply, and sanitation.

Natural capital: Environment

The environment plays a pivotal role in fostering economic prosperity and development, shaping the wealth and well-being of both current and future generations. Good environmental quality is a basic need for a healthy life for humans and ecosystems. In addition, natural resources produced by healthy ecosystems play a vital role in delivering services and livelihood support to billions of individuals, especially in rural and impoverished communities (Lynch et al. 2016; Pörtner et al 2022). The environment and biodiversity also hold intrinsic social and cultural value (Jackson and Barber 2013; O'Donnell et al. 2023) and they are a legacy that must be shared with future generations.

THREE PRIMARY CHANNELS FROM WATER TO PROSPERITY

Water plays a crucial role in determining prosperity, mainly through three channels: as safe drinking water, as an essential input for various economic sectors, and as a critical support for ecosystems.

Drinking water supply and sanitation

Drinking water is essential for human survival. For a healthy, productive life, that water must be clean. Access to clean water and safe sanitation affects all stages of human development, especially children's health and education, which determines future economic outcomes (Andres et al. 2018; Gould et al. 2011; Kremer et al. 2023). Safe water and sanitation are also critical for promoting gender equality and social inclusion. In many societies, women and girls bear the primary responsibility for collecting water, often at the expense of education, employment, and other opportunities (WHO/UNICEF 2023). Lack of proper sanitation facilities at school reduces girls' school attendance (Adukia 2017). Access to clean water and safe sanitation facilities therefore reduces the burden on women and girls, enabling them to participate more fully in social, economic, and educational activities (Koolwal and Van de Walle 2013).

Water for agriculture and food production and for other economic sectors

Water is an essential input in food production, and its reliable supply significantly affects food security. As a critical input for agriculture, water plays a fundamental role in meeting our daily food and nutrition needs. For instance, producing one kilogram of wheat requires at least 1,000 liters of water, the production of one kilogram of beef steak requires around 15,000 liters of water (FAO 2020), and 70 percent of all water withdrawals and 90 percent of water consumption are allocated to agricultural production. Food and nutrition affect health and cognitive development, particularly during the early stages of life. Drought-induced maternal malnutrition can have adverse effects that span generations for vulnerable individuals and communities (Damania et al. 2017).

Water is also significant for job creation, economic growth, and poverty reduction (Mueller and Quisumbing 2011; Mahajan 2017). By providing more reliable access to water, irrigation expansion over the past 75 years has transformed the lives of millions of small farmers (Jacoby 2017; Duflo and Pande 2007). It has increased labor demand, stable employment, and crop yields (by 20 percent to 24 percent) in developing countries. By 2000, it had also reduced equilibrium crop prices by one-third to two-thirds (Evenson and Gollin 2003; Pingali 2012), thereby increasing consumers' purchasing power and real income.

Water is essential for the forest, fisheries, energy, manufacturing, and transportation sectors. For example, hydroelectric power accounts for roughly 15 percent of the world's electricity generation and 40 percent in low-income countries. Water is also important for thermal and nuclear power plants as a coolant and as an input for the production of biofuel and biomass power plants. In addition, most global trade is transported by cargo ships across waterways, and reliable waterway systems are particularly important for agricultural exports (USDA 2022). Water scarcity and extreme rainfall shocks can hinder energy production, increase energy prices, reduce firm productivity, and disrupt shipping and trade (Islam and Hyland 2019; Islam 2019; Latham 2023; Wilkes et al. 2022; Arslanalp et al. 2023).

Ecosystems

Water provides a habitat for aquatic life, fosters biodiversity, and is a medium for nutrient transport within and between ecosystems. Water acts as a coolant to regulate temperature and influences or even defines weather and climate patterns. It creates landscapes through erosion and sedimentation. In short, water sustains life, fosters biodiversity, regulates climate, shapes our physical world, and makes our uniquely blue planet livable.

WATER SECURITY CHALLENGES THREATEN DEVELOPMENT OUTCOMES

Water is a crucial source of prosperity, but realizing its benefits requires sustainable management and development of water resources along with equitable and inclusive delivery of water services such as irrigation, water supply, and sanitation.

However, disparities in access to water resources and services are widespread. These challenges, further compounded by population growth and urbanization, pose a significant threat to shared prosperity. Globally, 2.2 billion people lack access to safely managed drinking water services, 3.5 billion people lack access to safely managed sanitation facilities, 2 billion people rely on health facilities without basic water supply, sanitation, and hygiene (WASH), and more than 800 million children attend school without basic WASH services (WHO/UNICEF JMP 2024).

While significant disparities in access to safe water also persist in high-income countries (Mattos et al. 2021), the challenges are more formidable for low-income and least developed nations. Countries with higher percentages of individuals living in extreme poverty also have higher percentages of people living without access to at least basic water and sanitation services. Despite an increase in global coverage, the access gap between the rich and poor remains large. In low-income countries, access has even regressed: in 2022, an additional 197 million people lacked safe drinking water and 211 million lacked basic sanitation, compared with the year 2000. Eight out of 10 people who lack access to at least basic drinking water services and 7 out of 10 without access to at least basic sanitation services live in rural areas, and little progress has been made in closing the rural-urban access gap in low-income countries over the past two decades (Chapter 3).

Unsafe water is a leading contributor to child mortality (Kremer et al. 2024). At the global level, during 2019 alone, poor WASH conditions contributed between 1.4 and 4.2 million deaths and between 74 million and 204 million disability-adjusted life years (DALYs) due to diseases such as diarrhea, acute respiratory infections, undernutrition, and soil-transmitted helminthiases (WHO 2023). Nevertheless, there are other diseases resulting in more deaths and health burdens from water pollution (fluorosis, lead poisoning and arsenic exposure), or from poor sanitation or hygiene (malaria, long-term child stunting, schistosomiasis, and trachoma, to name few. Lack of access to WASH also affects optimal cognitive development, school attainment, labor productivity, income, and job opportunities (Chapter 2).

Also evident are disparities in access to irrigation. While irrigation expansion over the past 75 years has transformed the global agricultural landscape, the benefits of irrigation have not been equally shared. Gender, land distribution, class status, and access to capital all play a role in determining the distribution of benefits within irrigating systems. Differential impacts can even be felt between continents–African rice farmers have benefited little from irrigation and related seed development, while at the same time they have to compete with low-cost rice produced at irrigated Asian farms.

Climate change is making the problem worse. It manifests through its impact on the water cycle. With global warming, there will be more unpredictable water supply, more frequent and severe droughts, and a higher risk of disease outbreaks after floods (IPCC 2023). These water shocks can lead to crop damage, lower food supplies and income, higher food prices, and increased risk of waterborne disease. Water shocks also threaten peace and stability. Studies show that rainfall anomalies are associated with increased incidences of conflict and social unrest, particularly in countries where rainfed agriculture is the dominant source of income (see, for example, Raleigh, Linke, and Dowd 2012; Hsiang, Burke, and Miguel 2013; Sarsons 2015; Koubi et al. 2021).

Droughts and floods affect all four building blocks of prosperity. However, the impact varies substantially across countries and socioeconomic groups. Developing countries and poor households are more exposed to climate shocks (Chapter 4). They are also more vulnerable to the impact of climate shocks because of their (1) higher reliance on natural resources for livelihoods; (2) inadequate infrastructure and water management systems to absorb shocks; and (3) limited capacity to recover from shocks.

Climate shocks can have significant and long-lasting impacts on vulnerable households. For instance, droughts and floods can lead to disinvestment in human capital development, with school dropout rates increasing as a coping strategy to deal with financial hardships caused by water shocks (de Janvry et al. 2006; Pham 2022). The poor are systematically uninsured or underinsured. Uninsured or partially insured climate risks can increase risk aversion (Liebenehm and Waibel 2018) and distort investment away from income-maximizing toward risk-reducing activities or, by discouraging investment altogether, lead to lower income growth in the long term. This combination amplifies the threat to the poor and can push more people into poverty and entrapment (Hallegatte 2012; Barrett et al. 2019). It was estimated that climate change and shifts in hydrological cycles could cause an additional 68 to 135 million people to fall into poverty by 2030 (Afino et al. 2020).

THREE TYPES OF POLICY INTERVENTIONS TO PROMOTE EQUITABLE AND INCLUSIVE WATER SECURITY

When water resources, infrastructure, and services are not adequately managed, developed and delivered, water-related challenges—issues with too much, too little, or too polluted water—can exacerbate inequalities and fragility. Throughout the value chain of water supply, from source to distribution, three types of interventions can significantly improve water security and concurrently reduce poverty and increase shared prosperity. These interventions aim to achieve: (i) resilience to extreme hydro-climatic risks; (ii) water resources development and coordinated allocation to different water uses; and (iii) equitable and inclusive delivery of water services.

While specific policy recommendations are often context dependent, this report highlights the following interventions that could improve water security and be pro-poor and inclusive:

- Enhancing resilience to extreme hydro-climatic risks for the poorest by
  - Setting up robust and inclusive early warning systems.
  - Establishing insurance programs for weather risks and mitigating exposure to hydro-climatic risks through regulations and financial support.
  - Scaling up social protection schemes to assist vulnerable communities impacted by floods and droughts.

- Improving water resources development, management, and allocation by
  - Scaling up nature-based solutions through innovative financing schemes and evidence-based approaches.
  - Enabling coordination and cooperation for water allocation through information sharing and financing incentives.
  - Adopting water accounting to inform water allocation decisions.

- Improving equitable and inclusive service delivery by
  - Scaling up financing through institutional and tariff reforms.
  - Establishing a participatory water governance to ensure transparency and accountability.
  - Creating an enabling regulatory and policy environment to promote innovations.
  - Improving coordination across institutions responsible for water, health, education and urban planning.

OUTLINE OF THE REPORT

The rest of the report is structured as follows. Chapter 2 discusses the various ways in which water contributes to the four building blocks of prosperity, providing both conceptual discussion and empirical evidence. Chapter 3 explores the main drivers and magnitudes of unequal access to water resources, and water services including irrigation and water supply and sanitation. Chapter 4 delves into the effects of climate change and explores how droughts and floods disproportionately affect the poor and vulnerable. Chapter 5 recommends policy actions to reduce inequalities in access to water resources and water services, improve resilience, and boost shared prosperity. The report concludes with a spotlight on several Indonesian programs that have implemented innovative approaches to promote the use of water for shared prosperity.

NOTES

1 The poverty line of $1.25 a day was based on a set of 2005 purchasing power parity exchange rates (PPPs), which account for differences in price levels and purchasing power across countries. The poverty line has since been updated twice to align with new sets of PPPs. It currently stands at $2.15 a day in 2017 PPPs.

2 The first dimension reflects the recent evolution of the World Bank's approach to measuring shared prosperity, which has evolved from a country-level measure, i.e., the growth rate in average income among the poorest 40 percent of a country's population, to a global-level measure, i.e., the global average shortfall in income from standard prosperity set at $25 per day (Kraay et al. 2023). This recent approach acknowledges that the bottom 40 percent of each country excludes a significant number of individuals who may be relatively well-off within their respective countries but still live in poverty based on a global standard.

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Why Water Matters for Shared Prosperity

CHAPTER 2

"Water is the divide between poverty and prosperity."

Rural development worker,
Maharashtra

2

CHAPTER

KEY MESSAGES AND FINDINGS

- Water is fundamental to promoting equality of opportunity for health and education. Lack of access to safe water and sanitation contributes to malnutrition and stunting and has a negative impact on optimal cognitive development and learning and skills acquisition. In 2019, poor WASH conditions were found to have contributed to a minimum of 1.4 million and up to 4.2 million deaths globally, as well as 74 million to 204 million DALYs. Public intervention to improve water access and safety among disadvantaged groups can help reduce gender and human capital disparities.

- Investment in water security supports job creation. Ensuring reliable water supply can boost productivity and employment in water-intensive and related sectors. Developing countries disproportionately rely on water-intensive sectors for employment.

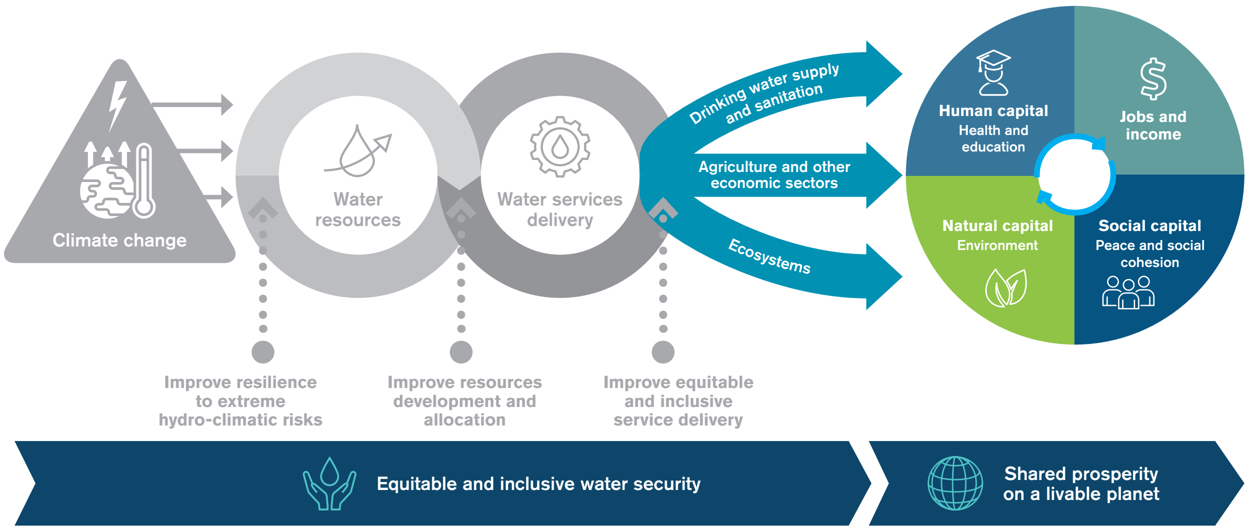
- Variations in water availability, exacerbated by climate change and environmental degradation, can reduce social cohesion, and heighten tension and grievances. Preventive policies to improve climate resilience and transboundary water cooperation are needed to avoid conflicts.

- Water sustains life, fosters biodiversity, and makes our uniquely blue planet livable. Natural resources produced by water-dependent ecosystems play a vital role in delivering services and livelihood support to billions of individuals, especially those in rural and impoverished communities.

Water is essential for life. Human life cannot exist without clean drinking water. Water also underpins food security. Producing a single kilogram of wheat requires at least 1,000 liters of water. Access to food, nutrition, and clean water, affects all stages of human development, especially in children and women, and the impact of inadequate access ripples across generations (Gould et al. 2011; Damania et al. 2017; Andres et al. 2018).

Abundant water is also important for forestry, fisheries, energy, manufacturing, and transportation sectors, playing a pivotal role in shaping a nation's wealth and prosperity. A flourishing economy is more likely to create decent jobs to lift the poor out of poverty, especially in developing countries, where the share of the economy that relies directly on water is high.

FIGURE 2.1 Why water matters for shared prosperity



Source: World Bank.
Note: Water security is defined as the availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems, and production, coupled with an acceptable level of water-related risks to people, environments and economies (Grey and Sadoff 2007). Water services include irrigation, water supply, and sanitation.

This chapter introduces a conceptual framework to illustrate the complex relationship between water and shared prosperity (Figure 2.1). Based on both a conceptual discussion and empirical evidence, the chapter describes how water security contributes to each of the four fundamental building blocks of prosperity outlined in Chapter 1—health and education (human capital), jobs and income, peace and social cohesion (social capital), and the environment (natural capital). This chapter also discusses how water insecurity can become a vulnerability multiplier and pose a threat to shared prosperity. Moreover, it presents evidence of how investing in water infrastructure and improving water services delivery foster inclusive and equitable growth.

WATER FOR HEALTH AND EDUCATION

Water affects health and education through multiple pathways. Aside from physiological impacts, water affects income, which serves as a primary transition mode. Wealth generated by irrigation, for example, spurs investment in health care and increases food expenditures and nutrition levels (Klinkenberg et al. 2008). Conversely, drought- and flood-induced poverty compels households to reduce their spending on food and education, leading to adverse health and education outcomes. Water security can also lead to conflicts, which can threaten physical safety and mental health.

HEALTH

Water security has long been understood as essential for preventing waterborne disease and sustaining food and nutrition. Emerging evidence suggests that problems with water access can also result in interpersonal violence (Tallman et al. 2023), stress (Young et al. 2019), and depression (Aihara et al. 2016; Cooper-Vince et al. 2018). This section briefly reviews evidence in these areas.

Drinking water supply and sanitation

One important mechanism through which water influences health is via the quality of drinking water and personal hygiene. Numerous studies have consistently demonstrated a direct correlation between the provision (or the lack) of drinking water, sanitation, and hygiene (WASH) services and health outcomes.

WASH services are particularly important for health during the early stages of life (Andres et al. 2018), affecting birth outcomes and imposing an enduring legacy on human capital development. For example, Brainerd and Menon (2014) found that a 10 percent increase in waterborne agrichemicals in drinking water during conception raises infant mortality by 4.6 percent and neo-natal mortality by 6.2 percent. These effects are most severe in children of uneducated, poor families in rural areas. DiSalvo and Hill (2023) examined the impact of drinking water contamination in community water systems on birth outcomes in Pennsylvania, United States. They found that even when contamination levels didn't trigger regulatory violations, they had significant adverse effects on birth outcomes, including low birth weight and preterm births.

Polluted water leads to various waterborne diseases, diarrhea being the most common. Diarrhea mainly affects children under five years of age. Persistent diarrhea in the early stages of life creates a condition called gut dysfunction, which prevents children from absorbing nutrients and developing normally. No matter how much food children with gut dysfunction eat, they will face stunting. Inadequate access to minimum WASH is estimated to account for around 50 percent of global malnutrition (Selim 2022). Malnourished children are also more vulnerable to waterborne diseases such as cholera. Unsurprisingly, the lack of access to WASH is also a key determinant of stunting, accounting for 54 percent of the variation in average height-for-age scores in children across countries. Stunted growth results in lower levels of human capital (Damania et al. 2019).

Water and sanitation inadequacies can lead to various other health issues throughout a person's life (Andres et al. 2018). This is true for both developing and developed countries. In the United States, polluted rivers used for recreation account for 90 million illnesses (including respiratory, eye, ear, and skin illnesses attributable to water recreation), which costs the health system between $2.2 and $3.7 billion annually (DeFlorio-Barker et al. 2018). At the global level, in 2019 alone, poor WASH conditions contributed to between 1.4 and 4.2 million deaths and between 74 million and 204 million DALYs caused by diarrhea, acute respiratory infections, undernutrition, and soil-transmitted helminthiases, and other WASH related diseases (WHO 2023).

Improving water quality is one of the most cost-effective ways to enhance health outcomes. A significant body of literature reports that water quality improvement based on household water treatment can reduce child diarrhea by 20–40 percent (Ahuja, Kremer, and Zwane 2010; Arnold and Colford 2007; Clasen et al. 2006; Fewtrell et al. 2005; Waddington and Snilstveit 2009). In Argentina, improvements in water supply infrastructure in slums even resulted in a 74 percent decline in diarrheal episodes among children (Galiani, Gonzalez-Rozada, and Schargrodsky 2009). A meta-analysis of 18 randomized trials by Kremer et al. (2024) found that water treatment reduces the odds of all-cause child mortality by a quarter. This implies a cost per DALY of well under $100, and less than $30 for delivery through the maternal and child health system. This suggests that water treatment is among the most cost-effective child health interventions available, representing a 30 to 70 times lower cost than the widely used threshold of 1x GDP per capita per DALY. In Bangladesh, Pitt, Rosenzweig, and Hassan (2012) found that despite little growth in rural wages and no change in average calorie intake, the average body mass index (BMI) by age and height of the rural population significantly increased thanks to improved water quality.

Input for agriculture and other economic sectors

Ensuring sufficient and reliable water for agriculture is crucial to food security and nutrition, which in turn support healthy and well-nourished people. For example, the large-scale irrigation expansion over the past 75 years has helped prevent the Malthusian catastrophe predicted by many. The expansion of irrigated areas has not only made food more abundant through increases in crop yields, but also reduced its cost. Evenson and Gollin (2003) estimate that global food prices would have been 35 to 65 percent higher if the Green Revolution seed technologies supported by irrigation expansion had not been developed. Price reductions provide substantial welfare benefits to consumers, in particular the poor, as they spend a high proportion of their income on food.[1] Wealth generated by irrigation may also spur investment in health care, for example, through the purchase of bed nets (Klinkenberg et al. 2008) or by increasing food expenditures and nutrition levels.

A more reliable water supply for agriculture, achieved through irrigation, is critical not only to the food supply available for farmers and their communities, but also to the crop selection and diet diversity (Von Braun, Hotchkiss, and Immink 1989). During the dry season, smallholder irrigation systems are commonly used to cultivate vegetables and fruits, which in turn improve the food security and nutrition of farmers and their communities, especially of people living in Sub-Saharan Africa, and of women and children (Pinstrup-Anderson and Hazell 1985).[2] Studies consistently indicate that women from irrigated farm households are more likely to meet their dietary needs than women from nonirrigated farm households (Baye et al. 2022). Irrigation improves diets and buffers seasonal dietary gaps, particularly in the case of poor subsistence farmers and rural and urban households that purchase irrigated farming products at local markets (Mekonnen et al. 2022).

Among Ethiopian and Tanzanian households that reported having faced drought, women from irrigated farm households had higher Women's Dietary Diversity Scores than women in nonirrigated farm households (Baye et al. 2022). Children from irrigated farm households in Ethiopia have Weight-for-Height Z-scores (WHZs)[3] with standard deviations that are 0.87 higher than those of children from nonirrigated farm households (Mekonnen et al. 2022). Similarly, in Tanzania, irrigation is associated with higher WHZs in children under 5 among households that experienced a drought in the five years preceding the study. In Niger, irrigation is associated with a 10 percent decrease in food insecurity, a 9 percent increase in food consumption expenditure, and improved dietary diversity (Kafle and Balasubramanya 2022).

In contrast, food deprivation due to extreme weather events such as droughts can cause poor nutritional status, with particularly detrimental effects on maternal women and children. Such impacts can have generational consequences for health and welfare. For example, studies found that women born during periods of below average rainfall grow up to be significantly shorter, less educated, and less wealthy. Moreover, the children of these women are more likely to be significantly below average size in terms of height for age, weight for age, or weight for height (Damania et al. 2017). This pattern mirrors findings from studies conducted in Indonesia that highlight the impact of poor early-life rainfall on adult height and wealth (Maccini and Yang 2009), as well as studies conducted in South Africa that link low early-life rainfall to higher rates of adult disability (Dinkelman 2017).

Physical safety and mental health

Lack of access to water leads to physical safety hazards, especially for women. For example, the exertion of hauling water has been reported as a cause of miscarriage (Pommells 2018; Collins et al. 2019; NCRI Women's Committee 2020). There is also an increase in physical, sexual, and emotional violence by men against their female partners when there are issues with household water (Collins et al. 2019; Tallman et al. 2023). Water insecurity has forced women to exchange sex for water (BBC News 2022; Merkle et al. 2023). Tensions and conflict arising from water scarcity and drought could affect health and physical safety if violence harms people or destroys water and health infrastructure.

EDUCATION

Education is a cornerstone for equality of opportunity. It is also at the forefront of global efforts to reduce poverty. The significance of knowledge in catalyzing economic expansion and facilitating an escape from poverty has long been documented, with pioneering works by Nelson and Phelps (1966), Romer Paul (1986), and Barro (2000). Gethin (2023) estimated that education is responsible for half of the worldwide economic growth. It is the foundation of 70 percent of the income gains experienced by the poorest quintile, and has played a role in 40 percent of the drastic reductions in extreme poverty since 1980. The impact of education extends to gender equality; education is credited for more than half of the rise in women's income share.

Throughout life, water exerts both direct and indirect effects on educational attainment. Drinking water quality, food and nutrition, and income are the primary channels through which water affects optimal cognitive development and school attendance throughout formal education (Figure 2.2).

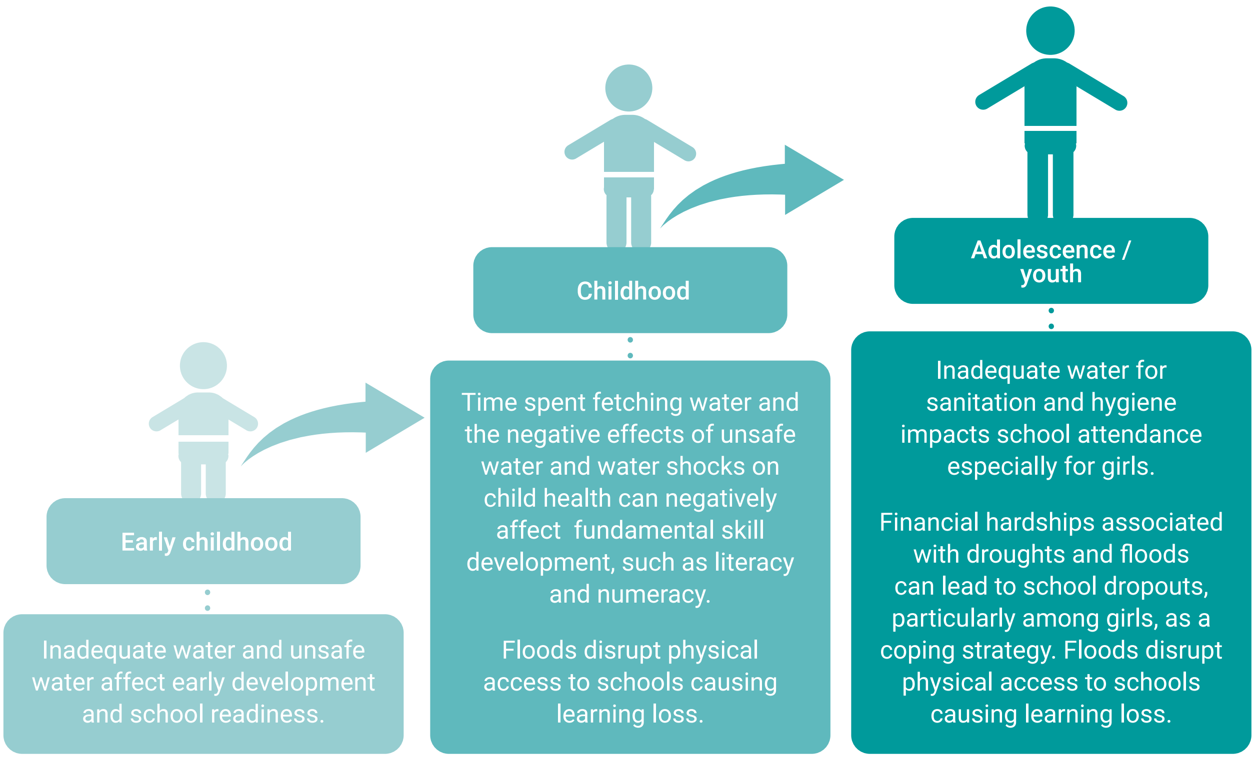
Cognitive development

Water plays a crucial role in cognitive development, particularly during the early stages of life. A meta-analysis conducted by the Center for Global Development found consistent evidence that exposure to lead, which is often found in polluted water, can hinder childhood cognitive development. Furthermore, the study found that lead exposure is responsible for one-fifth of the learning gap between high-income countries and low- and middle-income countries (Silverman et al. 2023). Lead is especially harmful to infants, who absorb it at rates four to five times higher than adults.

Without access to water, food production can be negatively affected, leading to malnutrition and other health issues that hinder cognitive development. A study conducted by Aguilar and Vicarelli (2022) found that children who experienced exogenous precipitation anomalies during their early years demonstrated enduring cognitive development deficits, with an impact ranging from 0.15 to 0.19 standard deviations. The study also identified adverse effects on children's height and weight, which help link the impact on cognitive development to deficiencies in food consumption and diet composition.

Public investment in basic water and sanitation provision has been shown to generate significant cognitive gains. For example, Chen et al. (2017) found that children in rural China who gained access to tap water during early childhood are associated with enhanced cognitive performance, with each

FIGURE 2.2 Water affects education from early childhood through school-age years



Source: World Bank

additional year of exposure resulting in a 0.109 standard deviation increase in cognitive test scores. The cognitive advantages are most pronounced when tap water access begins at least a year before birth, and they diminish when this access starts later.

Zhang and Xu (2016) found that a water treatment program in rural China in the 1980s increased average educational attainment of children by 1.1 years. The effect is more pronounced among rural girls, thereby narrowing the gender gap in education. In addition, the benefits are significantly higher for those exposed to treated water in early childhood.

Orgill-Meyer and Pattanayak (2020) added evidence linking early childhood sanitation improvements to sustained cognitive development and future labor market outcomes. Their study finds significant cognitive benefits for children in villages in India with higher latrine coverage, particularly among girls, when assessed a decade after the intervention.

Although the most severe negative impact on cognitive development occurs during early life exposure, poor water quality can affect cognitive capability and school achievement throughout a child's school-age years. For example, Asadullah and Chaudhury (2011) found that arsenic exposure from contaminated drinking water decreases mathematics performance among both primary and secondary school children. Marcus (2023) found that water quality violations in North Carolina, specifically bacterial contamination, were associated with a decline in math scores by approximately 0.037 standard deviations, particularly when the public was unaware of the violation. This impact is more pronounced in less affluent areas where students are more vulnerable to environmental factors.

Barde and Walkiewicz (2013) found that access to piped water accounts for an 11 percent increase in the standard deviation of average test scores of students in Brazil, indicating a significant boost to educational performance through its impact on cognitive abilities.

School attendance

Access to basic water and sanitation facilities at school is crucial for creating an effective learning environment. It decreases school absenteeism by reducing illness and establishing a safe and private environment for pubescent-age girls to manage their menstrual hygiene needs. Based on a meta-analysis, Jasper, Le, and Bartram (2012) found that schools' lack of access to water and sanitation facilities is correlated with higher rates of illnesses that can be detrimental to students' learning and overall school experience. The review also points to a significant reduction in diarrheal and gastrointestinal diseases with enhanced sanitation facilities. Adukia (2017) found school enrollment rates in India, especially among pubescent-age girls, significantly increase when sex-specific latrines are provided. Additionally, the presence of any latrine type benefits younger children, who are particularly susceptible to health risks from poor sanitation. Jasper, Le, and Bartram (2012) and Shah et al. (2022) also documented the link between the presence of sanitation and hygiene facilities and a decrease in school absenteeism, predominantly in developing countries.

The presence of proper water and sanitation facilities at home can also significantly improve school attendance rates. Zanoni, Acevedo, and Guerrero (2023) found that slum upgrading programs, including enhancements to water infrastructure, resulted in a significant increase in elementary school attendance in Uruguay. Students who benefited from slum upgrading programs had 28 fewer absences and a lower probability of being recurrent absentees. Ortiz-Correa, Filho, and Dinar (2016) revealed that children in households with access to piped water and sewerage systems achieved 0.7 and 0.8 more school years, respectively, compared with those without such access in Brazil. This positive effect is particularly pronounced in lower-income households.

Access to convenient and safe water at home can free up time that would otherwise be spent fetching water. In Ghana, reducing by half the time spent fetching water increased by 6 percentage points the share of girls attending school. In India, having access to a water source closer to home has been linked to improvements in female literacy (Andres et al. 2018). It has been reported in Kenya that waiting for water tankers or in long queues at boreholes has made children late for school, or even made them miss school completely (Dreibelbis et al. 2013).

Evidence suggests that among vulnerable households, dropping out of school is used as a coping strategy to deal with financial hardships caused by rainfall shocks. For example, Pham (2022) found that delaying primary school entry emerged as a coping strategy for the adverse effects of floods, especially among ethnic minorities in Viet Nam. As a result, excess rainfall, particularly during typhoon season, is associated with lower school enrollment among children. In Mexico, water shocks and natural disasters reduced community enrollment in education by 3.2 percentage points (de Janvry et al. 2006). The study also showed that once children were taken out of school, even temporarily, they were 30 percent less likely to continue with their studies than those who remained at school. In Pakistan, analysis of household surveys conducted before and after the 2010 floods shows that the floods led to a sharp rise in school dropout rates, with a measurable impact on literacy rates and education levels. As a response to the floods' impact on income and employment, many households withdrew their children from education (Khan and Hussain 2023).

Water shocks can have an unequal gendered impact on educational outcomes. Following a flood in a slum in Buenos Aires, Argentina, 70 percent of women reported suspending their education. This figure is nearly 50 percent higher than the proportion of men who reported suspending their education (Kristoff et al. 2020).

WATER FOR JOBS AND INCOME

Investment in water security contributes to job creation through multiple channels. First, investment in water infrastructure can lead to direct onsite employment for construction, maintenance, and operation of water facilities, such as dams, irrigation canals, and water supply and sanitation systems (Moszoro 2021).[4] Second, large investments could stimulate short-term growth and indirectly contribute to job creation in related industries (Schwartz, Andres, and Dragoiu 2009; Romer and Bernstein 2009). Third, and perhaps most importantly, water is a critical input for many economic activities, and ensuring reliable water supply could expand job demand by boosting productivity for water-dependent and related sectors, such as agriculture, energy, manufacturing, and transportation. Globally, about 78 percent of jobs have some level of water dependence, and 42 percent are significantly water-dependent (Das, Fisiy, and Kyte 2013). In addition, as discussed in the previous section, water affects health and education, and plays a critical role in boosting labor productivity and supply. Jobs created under this category tend to be long-term and broad-based, as is further discussed below.

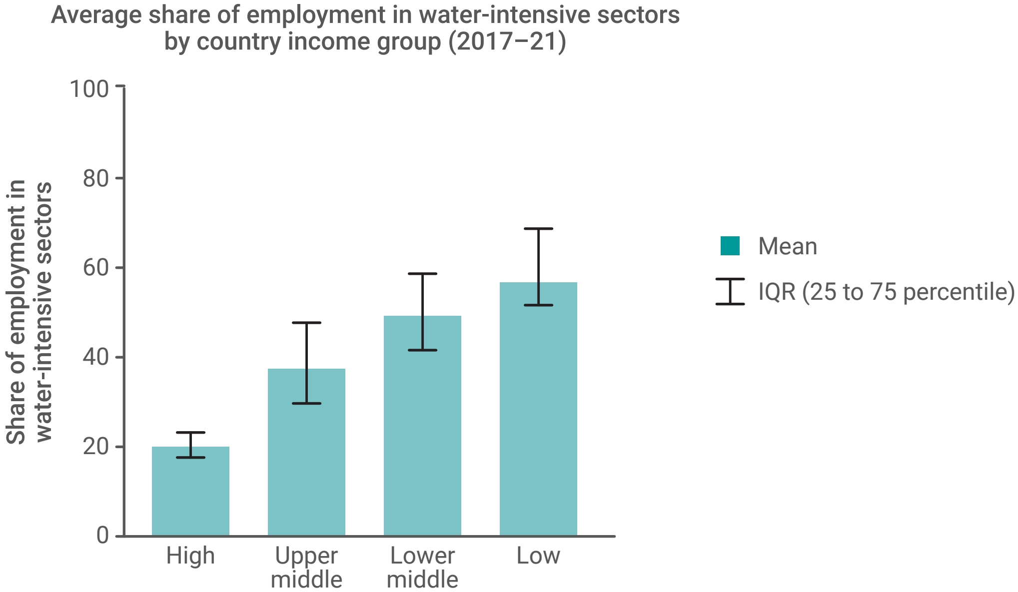
AGRICULTURE

Agriculture is the largest water consuming sector. Almost 70 percent of withdrawn water is used for agriculture, which is the main source of income of most rural poor. In low-income countries, jobs have a higher water dependency because of those economies' strong reliance on agriculture (Figure 2.3). Water availability has a significant impact on agricultural productivity and economies that rely heavily on rainfed agriculture (Figure 2.4). Damania et al. (2017) found that a dry shock (defined as rainfall that is at least one standard deviation below normal levels) can reduce agricultural yields by approximately 10 percent while a wet shock of a similar size can increase them by about 7.4 percent.

Irrigation expansion over the past 75 years has been a game changer for the global agriculture industry. By providing more reliable access to water, irrigation has significantly increased food production, creating jobs and reducing poverty. Irrigation expansion supported the Green Revolution, which is estimated to have increased crop yields in developing countries by 20 to 24 percent (Evenson and Gollin 2003; Pingali 2012). Independently, the tripling of irrigated area in China from the late 1950s into the early 21st century (Wang et al. 2020) and the development of related seeds underpinned perhaps the most rapid national poverty reduction in history (Huang, Yang, and Rozelle 2006), replacing the question "Who Will Feed China?" (Brown 1994) with "Who Will China Feed?" (Lohmar and Gale Jr. 2008).

More recently, the expansion of groundwater irrigation has transformed the lives of millions of small farmers, particularly in South Asia (Jacoby 2017; Duflo and Pande 2007). Irrigation enables more cropping seasons, including during dry periods. Increased output from irrigated land requires a

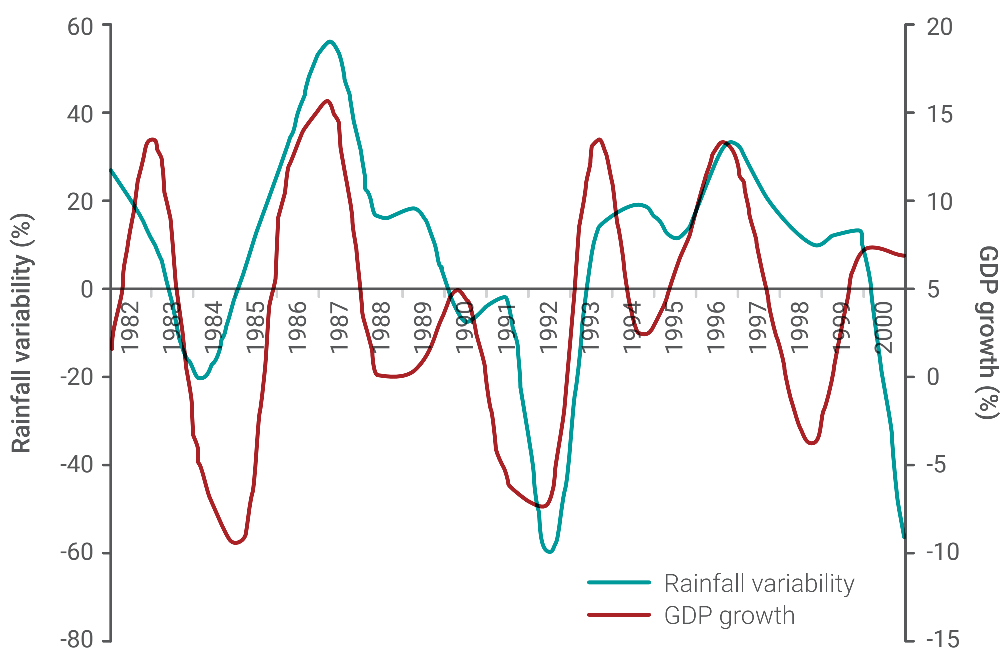
FIGURE 2.3 Developing economies disproportionately rely on water-intensive sectors for employment



Source: World Bank.

Note: Analysis is based on the International Labour Organization (ILO) Statistics employment data at ISIC-2 level. Water-intensive sectors include agriculture, forestry, inland fishing, and aquaculture; mining and resource extraction; water supply and sanitation; power generation; manufacturing of food and pharmaceuticals; and health care (United Nations 2021). Bars denote the mean in 2017–21 across countries and within each country income group. The inter-quartile range (IQR) denotes the range of values between the bottom 25 and bottom 75 percent of the observations. Income groups correspond to the groups the World Bank defined for its fiscal year 2024.

FIGURE 2.4 Gross domestic product growth was highly correlated with rainfall variability in Ethiopia (1982–2000)



Source: Petherick (2012).

substantial increase in the number of laborers and creates longer employment periods for the main and new cropping seasons (Hussain and Hanjra 2004). In India, for example, irrigated land exhibited a 50 to 100 percent higher demand for agricultural labor compared to rainfed land (Briscoe and Malik 2006).[5] In Bangladesh, modern irrigated rice cultivation has increased employment by 80 to 116 days per year per hectare. Moreover, the introduction of irrigation increases employment stability (Briscoe and Malik 2006) and benefits farmers from outside the irrigated area. During harvest periods, in-migration of landless labor and landed farmers from rainfed regions becomes prevalent (Sharma, Varma, and Joshi 2008).

The recently developed commercial horticulture sector, which has benefited from privately financed irrigation, has shown great employment potential in developing countries. The horticulture sector is labor-intensive and generates significantly higher income per unit of land and water, creating more on-farm and off-farm employment opportunities and leading to higher real wages in local economies. It is also a pro-poor sector because it benefits small farmers, particularly women.

In Kenya, for instance, the horticulture sector directly employs 4.5 million people in production, processing, and marketing. Another 3.5 million people benefit indirectly through trade and other associated activities, as the sector has rapidly emerged as one of the largest foreign exchange earners in the country (Kanyua, Waluse, and Wairimu 2015). Similarly, floriculture is highly profitable in the Philippines and Ethiopia, contributing to improved employment conditions. In India, the sector helps improve the socioeconomic development of tribal women in regions with harsh dry lands and few employment opportunities (Patel et al. 2018). In Pakistan, the floriculture business is concentrated among the small growers (Rafiq 2024).

ENERGY

Energy is another sector that relies heavily on water for production. Low-income countries disproportionately rely on hydro for power generation. Hydroelectric power accounts for roughly 15 percent of the world's electricity generation but, in low-income countries, it is, on average, responsible for 40 percent of electricity production (Figure 2.5). Water is also important for thermal and nuclear power plants as a coolant and as an input for the production of biofuel and biomass power plants. Furthermore, having an ample and reliable water supply is critical for facilitating the transition to sustainable energy and for implementing innovative technologies such as green hydrogen, water batteries, data farms, and chip factories. Because water and energy are so closely intertwined, water shortage can lead to electricity shortage. Countries like Brazil and South Africa, which rely on hydroelectric energy, face frequent power disruptions caused by insufficient water to effectively operate their turbines (De Souza Dias et al. 2018; IEA 2020). In 2023, a major drought simultaneously shrank Europe's hydropower and thermal power capacity, the latter due to insufficient cooling water.

As electricity is a critical input for the production of almost all goods and services, the spillover effects of water shortages on the economy and employment—through impacts on electricity supply—are likely to be much larger than the direct impacts of water shortages on agricultural and industrial activities alone. The impact of electricity outages on firm productivity is well documented (Allcott, Collard Wexler, and O'Connell 2016; Chakravorty, Pelli, and Marchand 2014; Fisher Vanden, Mansur, and Wang 2015; Fried and Lagakos 2020; Grainger and Zhang 2019; Zhang 2019). Mensah (2024) found direct evidence that electricity shortages can reduce the number of employment opportunities by almost 14 percentage points in Africa; these shortages mostly affect workers in nonagricultural sectors and those with skilled jobs.

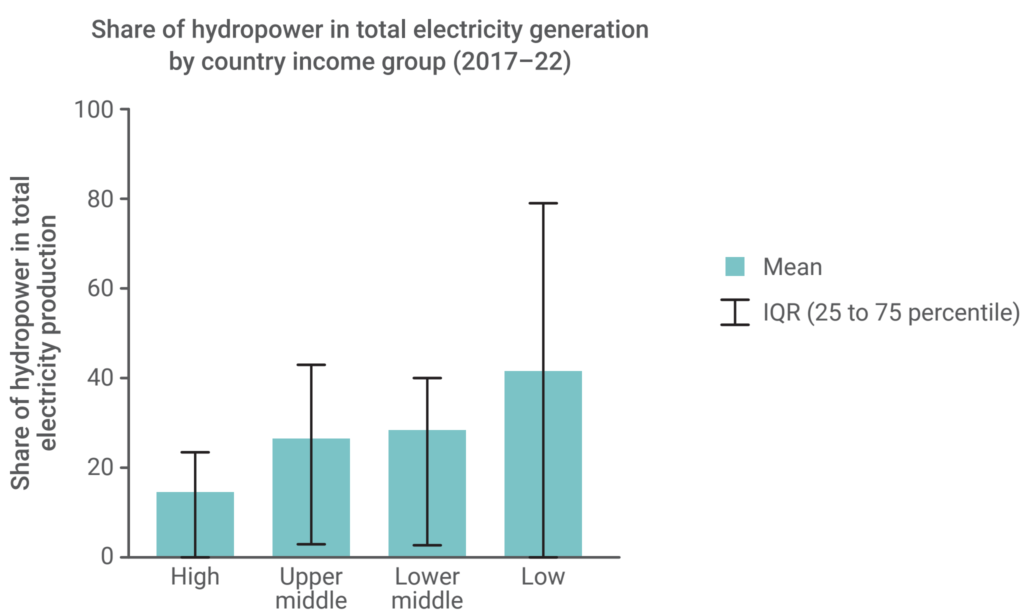
MANUFACTURING AND TRANSPORTATION

Water is critical to various manufacturing processes and plays a crucial role in industries such as food processing and mineral extraction. The World Bank Enterprise Survey (WBES) revealed that almost 16 percent of firms experience water shortages on a monthly basis (Figure 2.6). Small and medium-sized firms are hit particularly hard by these water shortages, both in terms of their frequency and duration (Figure 2.7).

Water scarcity that leads to shortages for industrial needs can negatively affect the productivity of industries and firms (Islam and Hyland 2019; Islam 2019), which in turn reduces their labor demand. In addition, Damania et al. (2017) found that large and prolonged shocks reduced labor income by 8 to 11 percent in Latin America. The informal workers, the self-employed, and workers in small firms are the most affected.

In addition, water plays an important role in transportation and trade. According to USDA (2022a,b), most global trade is transported by cargo ships across waterways, and reliable waterway systems are particularly important for agricultural exports. Almost 60 percent of global food miles pertain to travel by boat (Poore and Nemecek 2018).[6]

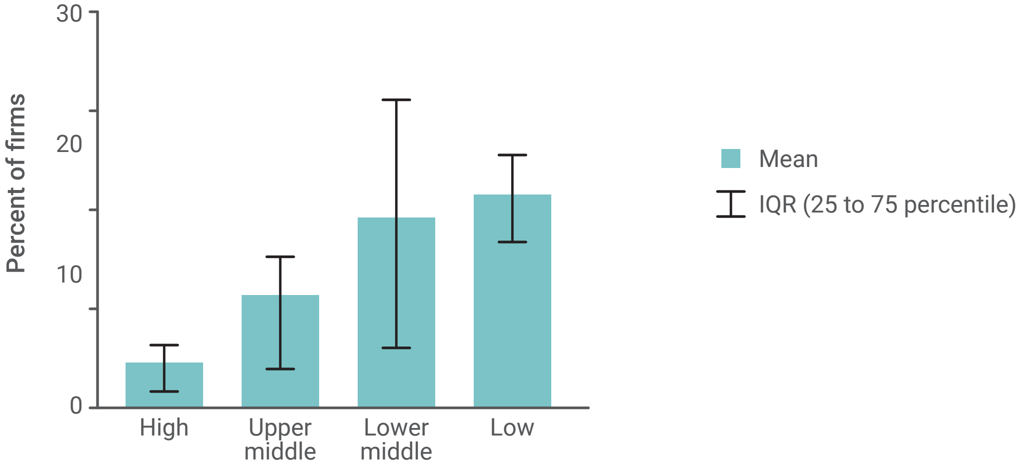
FIGURE 2.5 Low-income countries disproportionately rely on hydroelectric power for electricity generation



Source: World Bank.
Note: Analysis is based on data from Ember – Yearly Electricity Data (2023), Ember – European Electricity Review (2022), Energy Institute – Statistical Review of World Energy (2023) via Our World in Data. Bars denote the mean in 2017–22 across countries and within each country income group. The inter-quartile range (IQR) denotes the range of values between the bottom 25 and bottom 75 percent of the observations. Income groups correspond to the groups the World Bank defined for its fiscal year 2024.

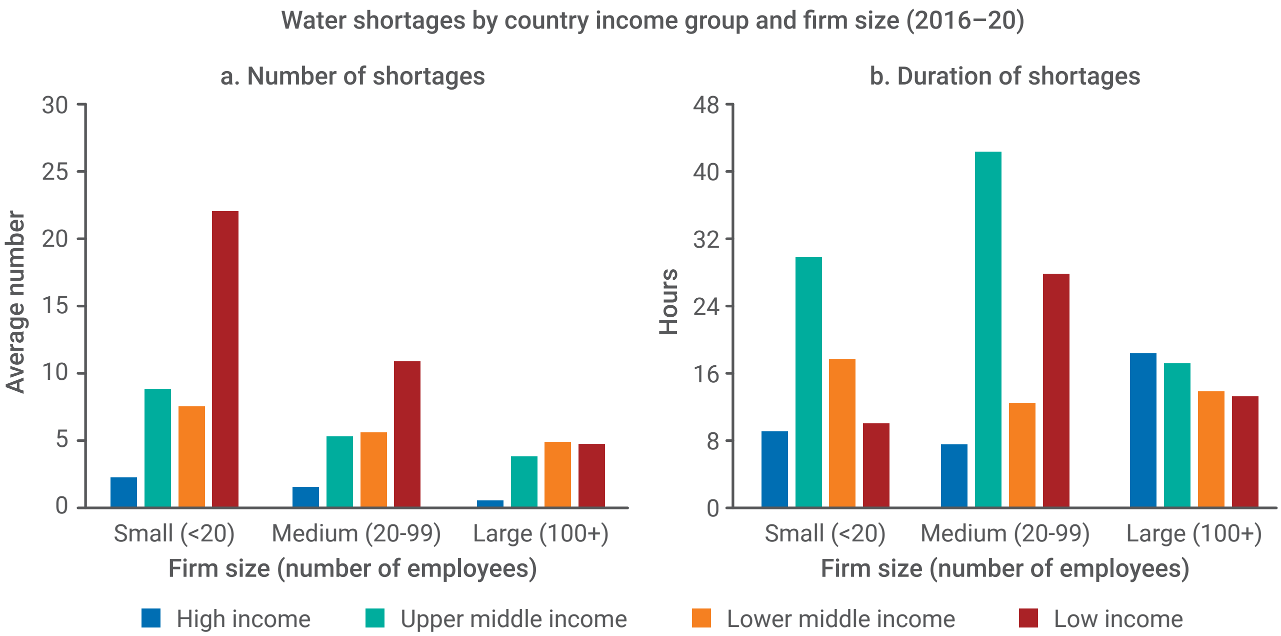
However, low water levels along waterways can disrupt the shipping of goods and cause vessels to run aground, which can greatly affect trade (Chan, Manderson, and Zhang 2024). In recent years, several key rivers, such as the Mississippi, the Rhine, and the Yangtze, have been hit by drought, affecting a billion tonnes' worth of cargo (Latham 2023; Wilkes, Wittels, and Vilcu 2022).

FIGURE 2.6 Firms in low-income countries are more likely to experience water shortages (2016–20)



Source: World Bank.
Note: Analysis is based on data from the from the World Bank Enterprise Survey (WBES). Bars denote the mean in 2016–20 across countries and within each country income group. The inter-quartile range (IQR) denotes the range of values between the bottom 25 and bottom 75 percent of the observations. Income groups correspond to the groups the World Bank defined for its fiscal year 2024.

FIGURE 2.7 Small and medium-sized firms face more severe water shortages



Source: World Bank.
Note: Analysis is based on data from the World Bank Enterprise Survey (WBES). Panel a presents the average number of water shortages in a typical month in the previous fiscal year. Panel b presents the average duration of the water shortages in hours if there were water shortages. Income groups correspond to the groups the World Bank defined for its fiscal year 2024.

The transport problem caused by low water levels is even more acute in developing countries with limited road networks, such as the Congo Basin countries. The Congo River directly serves more than 33 million people living within 50 kilometers of a navigable river, and rivers are the only means of transport. On the Oubangui tributary, the duration of low-water periods has increased from 4 days per year in 1971 to more than 200 days per year since 2002, disrupting transport for over half of the year (Trigg et al. 2022). This situation poses significant challenges for the people who rely on the river for transportation, trade, and other essential activities.

LABOR SUPPLY

Water affects the quantity and quality of labor supply through its impact on individual health, skills development, and time allocation choice. Lack of access to safe water can negatively affect adult health and can decrease productivity and employability. Pitt, Rosenzweig, and Hassan (2021) found that exposure to arsenic-contaminated groundwater severely affects cognitive and physical capabilities as well as educational attainment, especially of young males in Bangladesh. Their estimates show that cutting in half the average levels of arsenic would increase the proportion of young males in skilled occupations by 24 percent and the proportion of young men running nonfarm businesses by 26 percent. Additionally, water scarcity can lower labor participation by forcing individuals to spend more time fetching water, a burden that mostly falls on women and girls (Figure 2.8).

WATER FOR PEACE AND SOCIAL COHESION

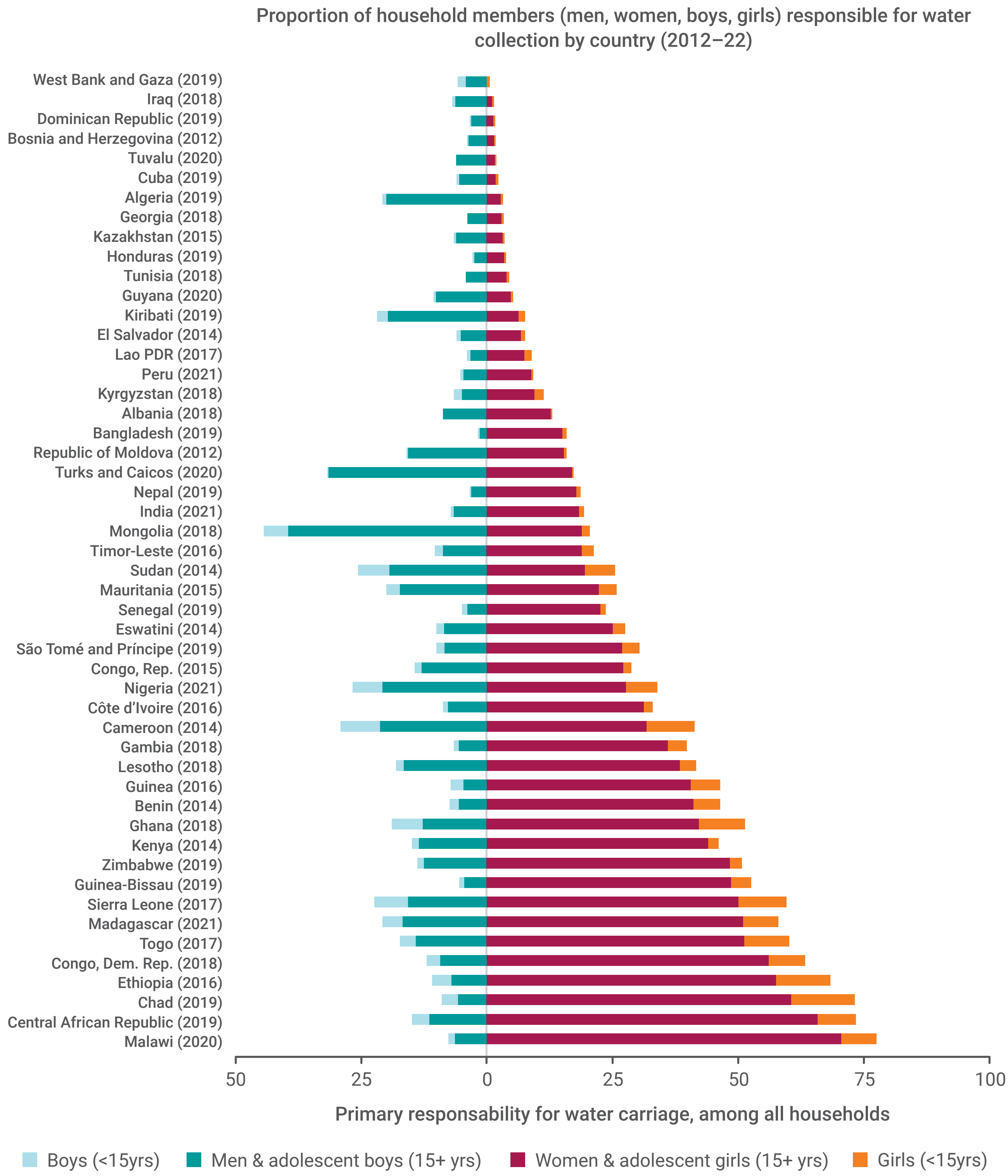
Water transcends the boundaries between sectors, communities, and countries. Transboundary river and lake basins are shared by 150 countries, cover 47 percent of Earth's land surface, and include 52 percent of the world's population (McCracken and Wolf 2019). Groundwater is also shared, with at least 592 transboundary aquifers identified (IGRAC 2015). The management and distribution of shared water resources can significantly affect social cohesion and the risk of conflicts. If water resources are managed effectively and equitably, they can foster trust, inclusivity, and cooperation among communities, ultimately promoting peace. If mismanaged, they can act as a threat multiplier, exacerbating existing conflicts or leading to new conflicts.

A vast body of literature explored the empirical evidence of the water-conflict link and found that variations in water availability, exacerbated by climate change and environmental degradation, can escalate conflicts at different scales and across regions (Raleigh and Kniveton, 2012; Hsiang et al. 2013; Sarsons 2015; Koubi 2019; and see Dell, Jones, and Olken 2014 for a review of earlier papers).[7]

The literature suggests several mechanisms through which water-related challenges can increase the risk of conflicts. These mechanisms can be broadly categorized into three groups: those related to the economic and labor market impacts of water shocks, those related to the social impacts of water shocks, and those related to direct competition for scarce resources. In addition, evidence suggests that the impact of water shocks on health can also contribute to conflicts. Evidence of these mechanisms is briefly reviewed in the rest of the section.[8]

First, water scarcity can lead to conflict through its effects on income, opportunity cost and state capacity. Favorable rainfall increases the chances of good harvests and the opportunity cost of engaging in violent activities, which in turn reduces rebel group recruitment. Conversely, droughts

FIGURE 2.8 Women as the carriers of water



Source: WHO/UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene (2023).
Note: The percentage figures for each country show the proportion of households in which different categories of family members are primarily responsible for water collection.

reduce agricultural outputs and income, and decreases the opportunity cost of engaging in fighting. Additionally, a decline in economic output could decrease government revenues and there by reduce the fiscal capacity of the government to maintain security (Besley and Persson 2010).

Miguel, Satyanath, and Sergenti (2004) revealed that adverse rainfall shocks resulting in negative GDP growth led to an increase in the incidence of civil wars in 41 African countries between 1981 and 1999. Similarly, Harari and La Ferrara (2018) found that agriculture relevant rainfall shocks significantly increased both the likelihood and intensity of conflicts in Africa from 1997 to 2011.

Based on data from 154 countries from 1963 to 2007, Burke and Leigh (2010) found that economic output contractions, particularly those resulting from adverse weather conditions, significantly heightened the chances of democratic change within the following year.

Guariso and Rogall (2017) found that rainfall anomalies can exacerbate grievances among politically marginalized groups and play a role in the emergence of ethnic conflicts. Using data covering 214 ethnicities across 42 African countries from 1982 to 2001, the study found that ethnic groups that had recently lost political power were more prone to engage in civil conflicts when adversely affected by rainfall shocks during crop-growing seasons.

Second, inadequate water management and access can generate grievance and disrupt trust and social contracts, which may lead to broader political instability. For example, rainfall anomalies can lead to food shortages and spikes in market prices. The rising price of staple crops in 2008 and 2011 led to massive protests and riots in dozens of countries, especially as urban consumers demanded relief from price inflation (Alexandratos 2008). Koren and Mukherjee (2022) showed that perceptions of food and water insecurity are mutually reinforcing, increasing social unrest in Kenya.

Through the food security channel, water scarcity not only has significant impacts within individual countries but also has spillover effects across the globe. For example, droughts can affect global food trade and food prices, which disproportionately affect countries heavily reliant on food imports. Food crises resulting from droughts have sparked protests and instability in other regions, even when being geographically distant (Schmeier and Gupta 2020).

Salihu and Guariso (2017) showed that unequal rainfall distribution exacerbates citizens' grievances over government performance and fosters mistrust between farming communities and nomadic herding groups, increasing the prevalence of civil conflict in Nigeria.

Fair et al. (2014) found that even in the absence of significant economic hardship, rainfall shocks can alter the political equilibrium by incentivizing political knowledge acquisition and citizens' attention over government performance.

Third, competition over scarce water resources and related services can lead to tensions and conflicts among various social groups and even between states. For instance, increased demand for water, especially in regions where water is scarce, can cause a rift between urban and rural water users, as well as conflict between upstream and downstream populations (Garrick et al. 2019).

Levy, Sidel, and Patz (2017) detailed instances of violence and unrest related to water scarcity across various regions. The study notes that most conflicts occurred because of disputes over water access and allocation. These conflicts largely arose in areas already affected by violence and involve farmers, pastoralists, and local communities in both rural and urban areas.

Harari and La Ferrara (2018) note that water issues triggered numerous conflicts between states in Sub-Saharan Africa over six decades (1958–2019). These conflicts sprang from diverse roots, such as the clash of interests between water-abundant upstream countries and their parched downstream neighbors, the unreliability of water and electricity supplies, land shortages for habitation and agriculture tied to water access, and contention over shared water resources, such as irrigation systems and dams.

Mozambique is an example of a downstream riparian state that is highly vulnerable to changes in water supply and demand by upstream states. A recent study suggests the potential for significant conflicts within the country resulting from increased water variability, reduced water availability, and increased population growth (World Bank 2023).

In the Inner Niger Delta, changing rainfall patterns and upstream infrastructure development have severely undermined the water security of farmers, herders, and fishermen, diminishing their income, quality of life, and livelihoods. Social cohesion has eroded, with different users competing over increasingly scarce and mismanaged water resources, often in a violent manner (World Bank 2019). These challenges create vicious cycles of water insecurity and conflict, exacerbating existing development issues.

Water shocks can trigger migration.[9] Migration—both within countries and across national boundaries —can lead to intensified competition over water and other basic services, such as jobs and housing, which may intensify intercommunal frictions and conflicts and increase demands on governments (Suhrke 1997; Reuveny 2007). Levy, Sidel, and Patz (2017) suggest that extreme weather events contributed to the onset of the civil war in Syria, where a severe drought from 2006 to 2010 led to mass migration from rural to urban areas, fueling political and socioeconomic instability.

Another pathway by which water can cause social unrest is through the effects of water on health. Using data from 140 countries during the period 1960–2010, Cervellati et al. (2017) conclude that epidemic outbreaks increase the risk of civil conflicts. Weather shocks, such as droughts and heat waves, significantly increase population exposure to infectious diseases, which in turn increase the likelihood of civil strife.

Notably, the dynamics of conflict and social unrest vary depending on local conditions, socioeconomic factors, and institutional responses by the state. Weather shocks typically do not lead to civil conflicts in wealthy, stable countries, and in the world as a whole (Dell, Jones, and Olken 2012).[10] In contrast, extreme weather events are more likely to lead to conflicts in countries with large populations, political exclusion of ethnic groups, and a low level of human development. In such countries, almost one-third of all conflicts, over the 1980–2016 period were preceded by a climate disaster within seven days (Ide et al. 2020).

Policies to improve resilience against climate change and transboundary water cooperation could mitigate conflicts and are most effective when implemented before crises escalate. They can enhance water security by reducing the risk of violent conflicts over water resources. In addition, cooperation on shared water resources can contribute to economic growth and jobs. In the Mashreq region, for example, economic modeling shows that the effects of water scarcity on the economy under a changing climate will be 60 percent less severe under a cooperative scenario (Taheripour et al. 2020).

WATER FOR THE ENVIRONMENT

Water is, literally, life. It provides a habitat for aquatic life, fosters biodiversity, and is a medium for nutrient transport within and between ecosystems. Water acts as a coolant to regulate temperature and influences or even defines weather and climate patterns. It creates landscapes through erosion and sedimentation. In short, water sustains life, fosters biodiversity, regulates climate, shapes our physical world, and makes our uniquely blue planet livable.

Natural resources produced by water-dependent ecosystems play a vital role in delivering services and livelihood support to billions of individuals, especially those living in rural and impoverished communities. Aquatic ecosystems are among the world's most complex and biologically diverse ecosystems that bring key resources to poor people. Indigenous people and rural populations rely heavily on water-related ecosystem services such as mangroves, wetlands, and fishing grounds for their livelihoods (IPCC 2022). In the Sahel region, where approximately one-third of the population falls below the international poverty line, groundwater-dependent ecosystems are regarded as lifelines for communities and are fundamental to the survival of various protected species (Rodella, Zaveri, and Bertone 2023).

Water not only is a crucial component of natural capital for economic growth but also has immense social and cultural value, including spiritual significance. For instance, indigenous water value encompasses both economic value and nonmonetary value, highlighting the cultural and historical links with water bodies, as described in the Cultural Water Paradigm (O'Donnell et al. 2023). Water also plays a significant role in the rituals and practices of various religions and beliefs. These diverse values underpin shared prosperity and hinge on inclusive governance.

However, poor water management has severely degraded water resources and the environmental services they create.[11] Globally, wetlands are disappearing three times faster than forests (Tickner et al. 2020). Likewise, many major aquifers are in serious decline (Jasechko et al. 2024). Most rivers no longer flow freely to the sea (Grill et al. 2019), and many no longer reach the sea at all. In many parts of the world, especially Eastern and Southern Asia, Northern Africa, and Western North America, human water use already surpasses local planet boundaries, leaving no water for environmental requirements (Kulionis and Pfister 2022). Reduced water availability can lead to altered nutrient availability and metabolism, affecting the stability of corals, and decreasing their health (Morris et al. 2019). Additionally, it can affect soil biodiversity, modify vegetation dynamics, and alter soil physical properties, ultimately influencing ecosystem services related to soil formation and water regulation (Keesstra et al. 2016).

Water pollution poses a significant threat to natural environments and ecosystems and is an increasing concern for both poor and rich countries (Damania et al. 2019). Industrialization, agricultural practices, natural factors, and inadequate water supply and sewage treatment facilities are all sources of water pollution. When water pollution is unchecked and continues to increase, it can alter and disrupt the natural environment and ecosystems. Numerous studies have shown that water pollution is a major contributing factor to the deterioration of Earth's ecology, affecting the quality of water and aquatic ecosystems, as well as living organisms (Morin-Crini et al. 2022; Lomova et al. 2019). Poor water quality also threatens economic growth, harms public health, and imperils food security. Desbureaux et al. (2019) estimated that downstream regions of heavily polluted rivers have experienced economic growth reductions ranging from 1.4 to 2.5 percent. This affects low-income countries by dragging their economic growth rate (which is higher in relative terms) and affects high-income countries' total value of output (which is higher in absolute terms).

Declining water availability and water pollution together have degraded global freshwater ecosystems. Since 1970, an estimated 30 percent of natural freshwater ecosystems have disappeared (Tickner et al. 2020) and the population of freshwater species has plummeted by 83 percent (WWF 2022).

CONCLUDING REMARKS

Water security is crucial for fostering shared prosperity and inclusive growth. Improving water access and safety can reduce gender and human capital disparities among disadvantaged groups and ensure long-term social cohesion and peace. However, mismanagement of water can lead to forgone development opportunities, environmental degradation, and conflict. Despite efforts to improve water access, inequalities persist, and climate change can exacerbate these inequalities. The next two chapters examine evidence of inequalities in water access and disparities in the effects of climate change across various income and social groups.

NOTES

1 In many Sub-Saharan African countries, food expenditures often represent more than 40 percent of income compared with less than 7 percent in the United States (Zeballos and Sinclair 2023). However, the lowest quintile of income earners in the United States also spend an average of 40 percent of income on food.

2 However, irrigation could also lead to monocropping and associated negative impacts on nutrition. For example, according to Hossain, Naher, and Shahabuddin (2005), an increase in rice production resulting from investments in small-scale irrigation in Bangladesh led to increased rice intake and reduced dietary diversity among the poorest households.

3 A z-score is a statistical measure that quantifies the number of standard deviations a data point is from the mean of the dataset. It is used to standardize data and compare individual data points to a standard normal distribution (i.e., a distribution with a mean of 0 and a standard deviation of 1). A positive (negative) z-score indicates that the data point is above (below) the mean. The WHZ indicates how many standard deviations the observed weight is above or below the median weight for a specific height, adjusted for age and gender. A higher (lower) mean WAZ indicates a higher (lower) weight relative to height compared to the reference population.

4 Moszoro (2021) found that investing in water and sanitation has the potential to generate the highest direct employment opportunities compared with investing in other infrastructure, such as electricity, roads, schools, and hospitals in low-income countries.

5 Although the expansion of irrigation has a positive impact on jobs growth, it is important to note that in areas where irrigation is supplied by groundwater, excessive groundwater extraction poses a serious threat to the long-term sustainability of job, income, and equity of a society (Fischer et al. 2022). It is crucial to implement sustainable agricultural water management practices, such as by adopting cost-reflective pricing of water and electricity for groundwater-supplied irrigation, to avoid groundwater over-extraction. Chapter 5 delves deeper into policy recommendations for sustainable agricultural water management.

6 Food miles are defined as distance covered multiplied by quantity of food transported.

7 Conflict has been defined as organized rebellion but also more broadly as disruptive activities, such as demonstrations, riots, strikes, communal conflict, and antigovernment violence. For empirical literature, conflict has been measured by both incidence and severity, such as deadliness and diffusion within a geographic area.

8 In addition to being a driver of conflicts, water has been used as both a weapon and a target in conflicts. Borgomeo et al. (2021) and Gleick (2019) reviewed water-related violence in the past three decades in the Middle East and North Africa region, reporting a growing trend of violence when water infrastructure is deliberately attacked or used as a tool of war—violence that exacerbates the humanitarian crises in conflict zones.

9 The 2000–22 droughts in Somalia forced more than 1.3 million people to abandon their farms and migrate to displacement sites (NASA GHRC 2023; Climate Hazards Center 2022).

10 Results from studies on the relationship between rainfall effects and conflict have not been entirely unambiguous. For example, Buhaug (2010), Ide (2017), and Liang and Sim (2019) found no significant relationship between rainfall shocks and civil conflict. In addition to differences in methodological approaches and data (such as country-level precipitation and conflict data versus more disaggregated data), heterogeneity in rainfall effects on conflict may explain the discrepancy.

11 Deforestation and land degradation also contribute to deterioration of water resources (Curtis et al. 2018; Medvigy et al. 2013), and both tend to occur more frequently in developing countries (Curtis et al. 2018; Hughes et al. 2020).

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Inequalities in Water Access

CHAPTER 3

"Water, water everywhere, nor any drop to drink."

Samuel Taylor Coleridge,
The Rime of the Ancient Mariner

3

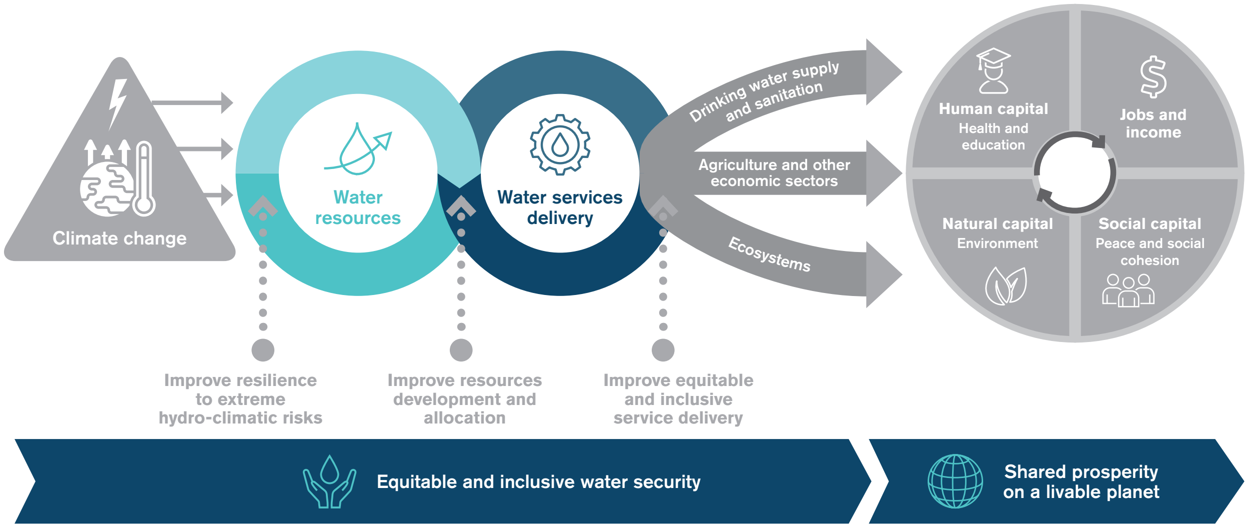
CHAPTER

KEY MESSAGES AND FINDINGS

- Population growth, urbanization, and climate change will exacerbate the global disparity in water access. By 2100, Africa is projected to experience a 64 percent per capita reduction in freshwater resources, in contrast to a marginal net increase of 0.4 percent in Europe. Low-income countries are also affected by higher seasonal rainfall variability, compounding their challenges in accessing reliable water sources.
- Irrigation expansion has transformed global agriculture in the past 75 years, but its benefits and costs are not equally shared. Factors such as gender, land distribution, and access to capital determine the distribution of benefits within irrigating communities.
- Access to safely managed water and sanitation services has improved in all country income groups. However, in low-income countries, population growth has outpaced the increase in access rates. Since 2000, the number of people without access to safely managed drinking water and basic sanitation in low-income countries has increased annually, rising by 65 percent and 66 percent, or by 197 million and 211 million people, respectively.
- In low-income countries, access to water services is available in less than half of the schools and less than three-quarters of the health facilities, while access to sanitation services is available in less than three-quarters of school and health facilities. Limited progress has been made since 2014 toward improving this situation.
- High poverty overlaps with low access. Globally, about 450 million people live in high-poverty and low-water-access hotspots, and about 1 billion people live in high-poverty and low-sanitation-access hotspots. If current trends continue these numbers could double by 2050.

Economic growth and prosperity hinge on water resources. However, billions of people currently contend with diverse forms of water scarcity. Beyond physical water scarcity—insufficient water to meet all demands—many parts of the world face economic water scarcity. This situation arises when “human institutions and financial capital limit access to water, even though water in nature is available locally to meet human demands” (IPCC 2022).

FIGURE 3.1 Access to water resources and services is essential to realize the benefits of water



Source: World Bank.
Note: Water security is defined as the availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems, and production, coupled with an acceptable level of water-related risks to people, environments and economies (Grey and Sadoff 2007). Water services include irrigation, water supply, and sanitation.

The existence of water "haves" and "have nots" within and across communities and countries, contributes to today's rising global inequality and fragility. This chapter delves into the drivers of inequalities, specifically with regards to access to water resources and services, including irrigation, water supply, and sanitation (Figure 3.1). It reveals that the benefits and costs of irrigation are unequally shared. Drawing on the latest data on poverty and water access, it further assesses the extent of and trends in inequalities in access to water and sanitation services. It finds that despite an increase in water and sanitation services globally, the access gap between the rich and poor remains large.

INEQUALITIES IN ACCESS TO WATER RESOURCES

Earth's accessible freshwater is unevenly distributed. China and India represent about 36 percent of the world's population, but only hold about 11 percent of its freshwater. On the other hand, North America has about 5 percent of the world's population but 52 percent of its freshwater (Pekel et al. 2016). In Africa, the Democratic Republic of Congo possesses more than 50 percent of the continent's entire water resources. Hotspots in the Sahel, Southeastern Africa, and South and Central Asia are facing the highest water stress (Map 3.1).

Three trends will exacerbate this inequality. The first is population growth. Population is a major driver of increasing water scarcity (Kummu et al. 2010). Although water scarcity is increasing in most regions worldwide, it particularly affects developing countries, which are expected to account for nearly all global population growth in the coming decades. Analysis conducted for this report indicates since 2000, per capita renewable water resources have decreased by 25 percent on average globally but by 43 percent in low-income countries. By the end of the century, a staggering 64 percent per capita reduction in freshwater resources is projected for Africa, in contrast to a marginal net increase of

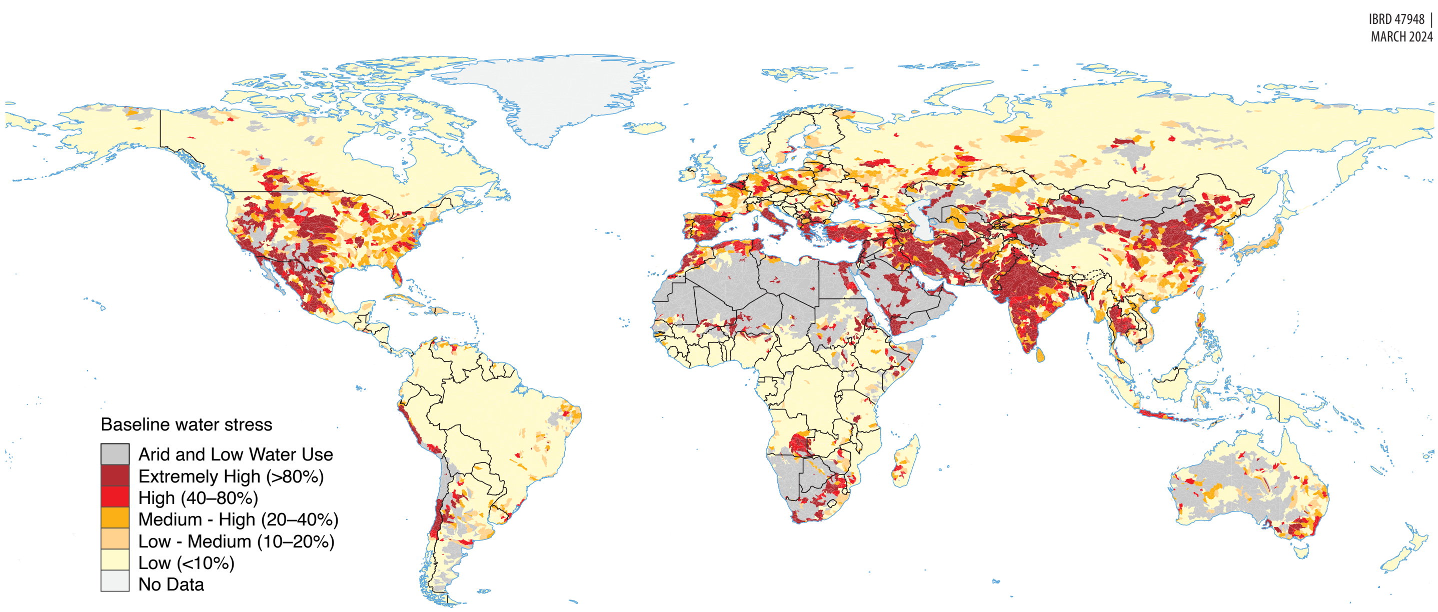
0.4 percent for Europe (Figure 3.2). Expected income growth, coupled with a shift in dietary preferences, could worsen water stress in developing countries (Box 3.1).

The second is urbanization. Global urban populations are expected to surge by approximately 2.5 billion people by 2050, with 90 percent of this growth expected in South Asia and Sub-Saharan Africa (United Nations 2019). Almost 7 of 10 people are expected to live in a city by 2050 and urban water demand will increase by 80 percent (Florke, Schneider, and McDonald 2018). Yet, the fastest-growing cities tend to be the poorest (McDonald et al. 2014). They face significant financial and institution constraints to expand water infrastructure and services to accommodate an increasing population. Further exacerbating the problem, many of the fastest-growing cities are in regions with minimal rainfall and terrain characterized by poor water retention (Figure 3.3). As a result, water will remain a perennially scarce resource in these cities.

Unplanned urban growth resulting in low-density development undermines inclusive water supply (Appendix A). Urban form is strongly linked with proximity to infrastructure and water. Remote areas generally experience higher levels of poverty and social exclusion. Thus, unaffordable water is a persistent struggle in poor and remote neighborhoods. Sprawling cities incur higher water services costs because most of their population is far from the city center. In Asian cities, for example, more than half of the population lives in the city center, but in Africa, less than 20 percent of the population lives there. Notably, African cities are highly sprawled, so the challenge of ensuring water and sewage will be more significant.

Although urbanization efficiently increases proximity to critical infrastructure and amenities, many cities worldwide are already under water stress (McDonald et al. 2014). With rapid urbanization and limited infrastructure and water resource availability, more cities will experience generalized

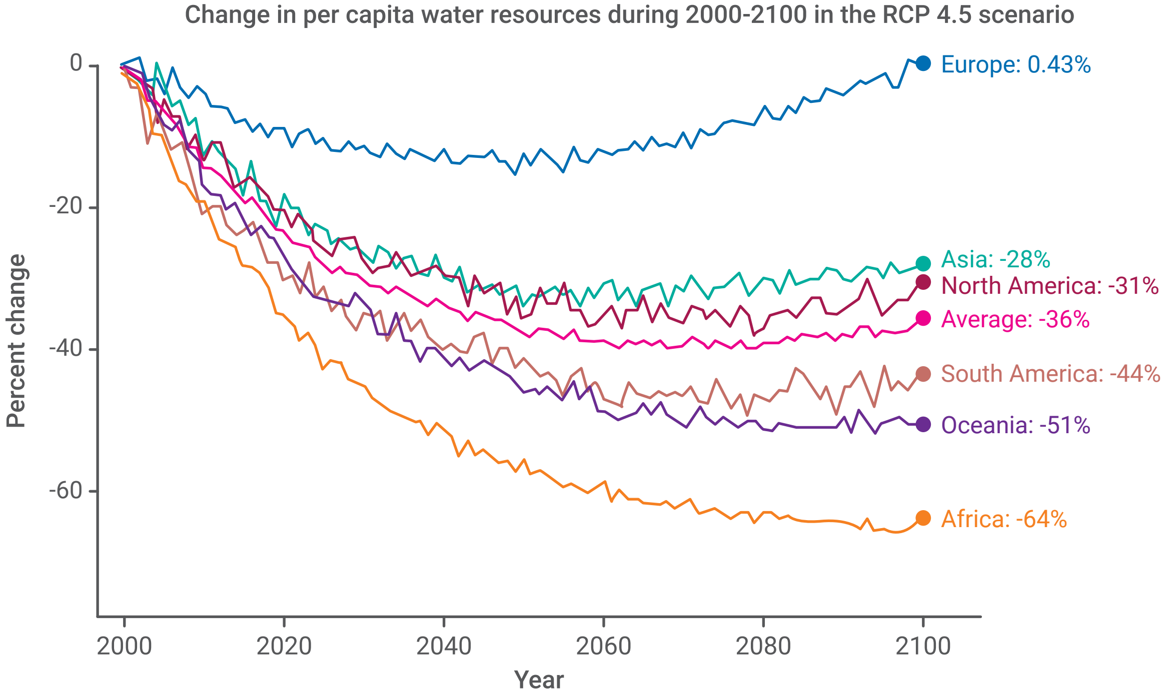
MAP 3.1 Water scarcity worldwide



Source: Water Resources Institute (WRI) Aqueduct.
Note: Water stress is measured by the ratio of water demand and renewable water supply accounting for environmental flow requirements.

interruptions of essential water services, an event known as "day zero" (Bischoff-Mattson et al. 2020). Due to the uneven distribution of resources and mobility capacity, day zero will greatly impact poor households (Chi et al. 2022).

FIGURE 3.2 Africa is expected to experience the most significant decline in per capita renewable water resources by 2100



Source: World Bank.
Note: RCP = Representative Concentration Pathway. The estimation is based on global downscaled precipitation projections from the National Aeronautical Space Administration and population data from the International Institute for Applied Systems Analysis.

BOX 3.1 Income growth and water consumption

Development goals include improvements in income. However, growing incomes drive dietary changes, with significant water implications. One of the most important changes is the shift toward meat consumption. As incomes grow, per capita meat consumption rises (Figure B3.1.1). Depending on the livestock type and production processes, a kilogram of meat requires 2–10 kilograms of feed grain (FAO 2006). Every kilogram of grain consumes 1,000–3,000 liters of water (Zwart and Bastiaanssen 2004; Mekonnen and Gerbens-Leenes 2020). Thus, the water required to meet food demand grows even faster when incomes grow.

As incomes reach a given level, possibly $40,000 per year (Whitton et al. 2021), per capita meat consumption plateaus, suggesting that future meat demand growth will occur in countries currently classified as poor and lower-middle income (OECD and FAO 2023) and are already more likely to be water scarce. This meat demand growth will increase pressure on domestic water sources, reliance on imported feed grown with water from other regions, or both.

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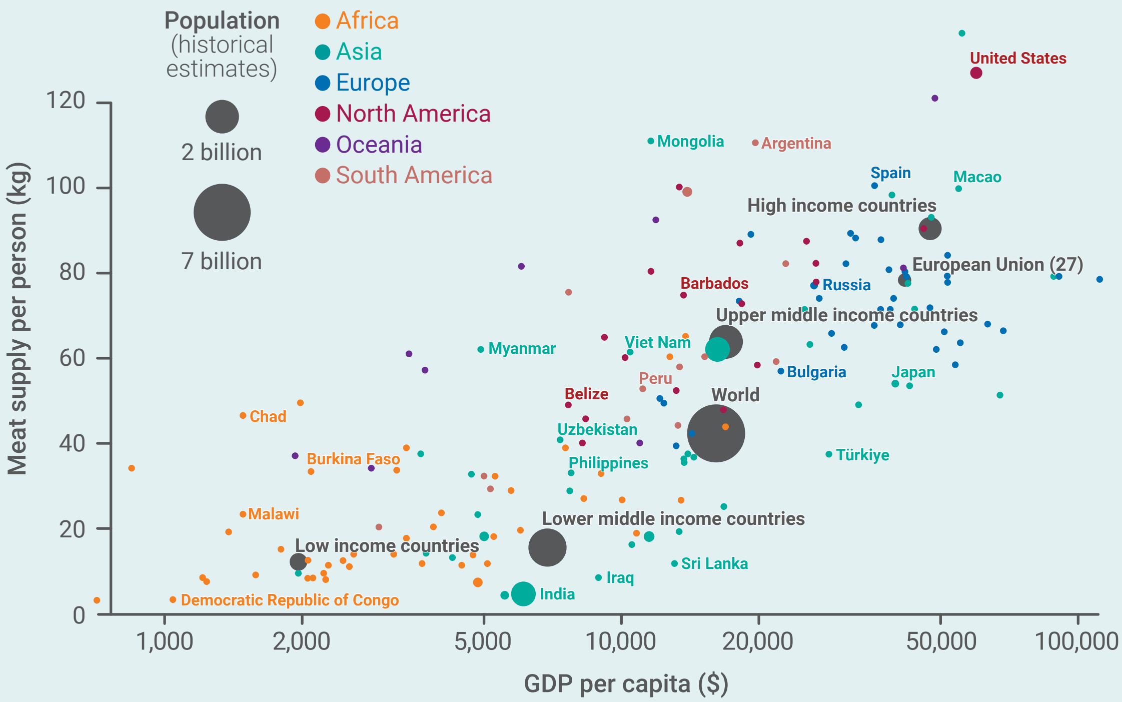
Box 3.1 *continued*

FIGURE B3.1.1 Average meat consumption per capita versus GDP per capita (2020)

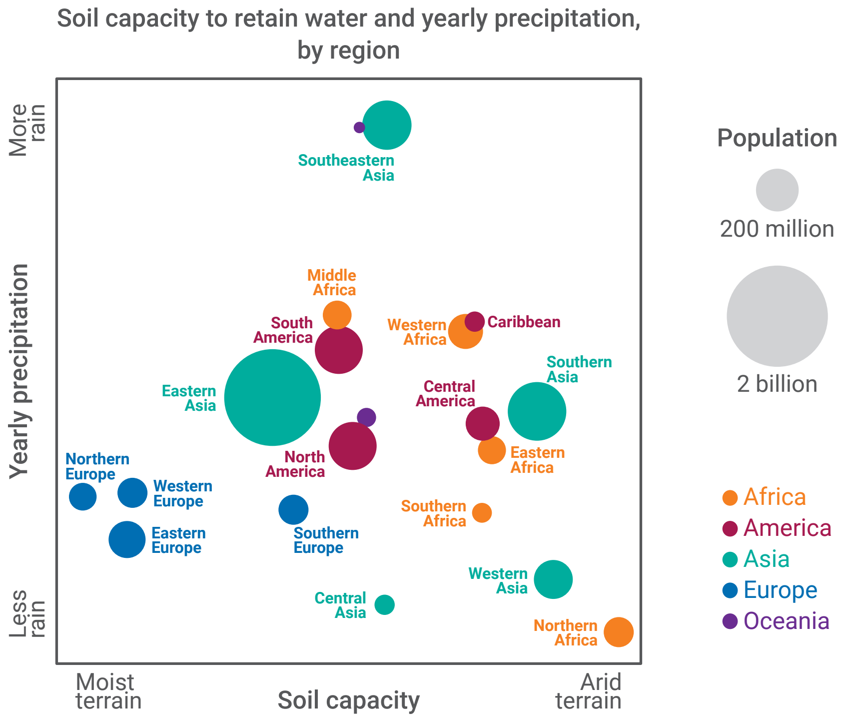


Source: FAO (2023), and World Bank (2023). This box was contributed by Mark Giordano.
Note: GDP = Gross Domestic Product. Meat consumption is measured in kilograms per year. GDP is measured in international dollars to account for price differences between countries.

This unprecedented urban expansion also creates pressure for water reallocation and potential competition between water use for rural livelihoods and water use for urban development. Approximately 400 million urban residents rely on water transfers from rural areas, with many depending on water from undocumented or informal sources of water (Garrick et al. 2019). Consequently, cities import up to 500 billion cubic meters of water per day from rural areas, which travel across canals and other regional water infrastructure that spans 27,000 kilometers (McDonald et al. 2014).

The reallocation of water from rural to urban areas has traditionally been carried out through three mechanisms—administrative decisions, market transactions, court decisions—or some combination of the three, with the landless poor least likely to be involved in decisions (Meinzen-Dick and Ringler, 2008). Administrative decisions, involving the construction of long-distance or inter-basin rural-to-urban water transfers, are the most well documented (Garrick et al. 2019). Involuntary and uncompensated reallocation projects often lack consultation with those in the source region, and the monitoring of their social and environmental impacts is limited. Furthermore, the distributional effects of rural-urban water reallocation are not well documented, leading to the perception that it is a zero-sum dynamic where cities benefit at the expense of rural and agricultural communities (Molle and Berkoff 2009). Even when both rural and urban regions benefit, cities tend to capture the majority of the gains, as illustrated by the iconic example of the Owens Valley transfer to Los Angeles (Libecap 2009).

FIGURE 3.3 Cities located in South Asia and Africa typically experience lower levels of rainfall and have soil with a limited capacity for water retention



Source: World Bank.
Note: Soil capacity to retain water (horizontal axis) and yearly precipitation (vertical axis) varies among regions. Color corresponds to the region and disc sizes correspond to the population. For each region, the value is the average soil capacity and precipitation observed in its cities, weighted by the population. Data on soil capacity to retain water was obtained from the Global Aridity Index, which uses evapotranspiration processes and rainfall deficit for potential vegetative growth. The rainfall is the average monthly precipitation between 1970 and 2000, aggregated to a yearly value. Most European cities have high levels of soil capacity to retain water, so even with low levels of rain, the terrain is favorable for water retention. Also, in cities in all regions of America, there is less capacity to retain water than in European cities, but it is rainier, so there are also some favorable conditions for ensuring access to water. Some cities in Asia have more favorable conditions related to water scarcity than others. On average, cities in Southeastern Asia receive the highest yearly amount of rain, and their soil has a reasonable capacity for retaining water. Yet, cities in Western Asia are among the regions with the smallest amount of yearly rain and challenging soil capacity. A similar situation occurs in cities in Africa. Cities in Middle Africa have high amounts of yearly rain and soil capable of retaining water. Yet, other parts of Africa are less favorable in terms of water scarcity. In cities in Southern Africa, rain is less frequent, and the terrain tends to be less favorable. Cities in North Africa and in Western Asia are in the most challenging region in terms of water scarcity. Those are cities where it rarely rains, and when it does, the soil does not remain humid for long periods.

When rapid urbanization outstrips the capacity of water institutions, unplanned or poorly managed water reallocation can exacerbate rural-urban inequalities and led to negative externalities for third parties (Garrick et al. 2019; Pearsall et al. 2021). These externalities range from the disruption of irrigation return flows that support downstream farmers to the loss of livelihoods and productivity as agricultural regions are forced to shift from irrigation to dryland farming. Without adequate safety nets and compensation mechanisms, involuntary water reallocation can reduce income for landless agricultural labor, increase pumping costs for the poor as water tables decline, and disrupt firms across the food value chain and regional economy (Garrick et al. 2019; Turley 2023; Pearsall et al. 2021; Raina et al. 2019).

The third trend is climate change which is expected to make water supply more unpredictable. In addition to leading to more frequent and severe extreme weather events, such as floods and droughts (further discussed in Chapter 4), climate change will also result in higher seasonal variability. The seasonal variability of water supplies, measured as the average within-year variability, exacerbates physical water stress. According to the Intergovernmental Panel on Climate Change (IPCC), approximately 4 billion people, or half of the world population, experience water stress for at least one month per year (IPCC 2022).

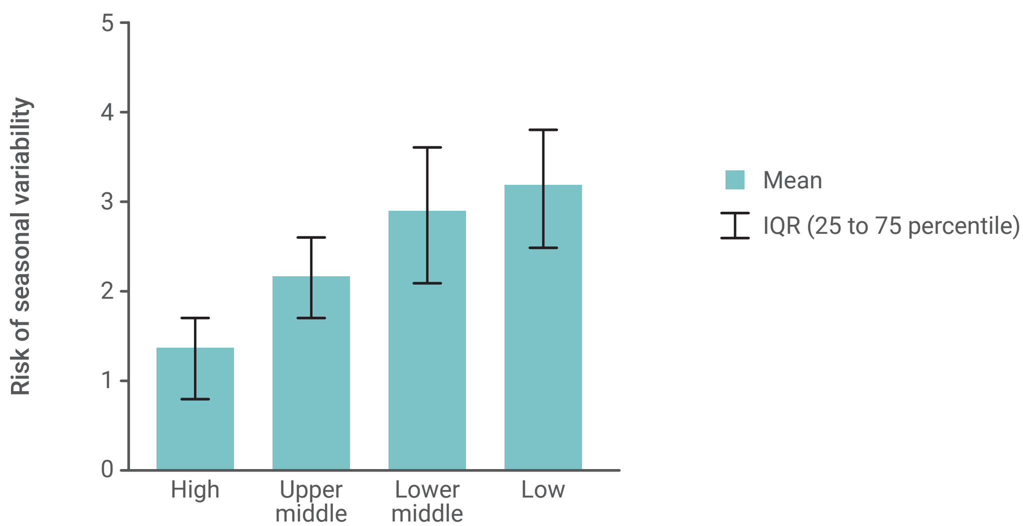
Low-income countries are on average facing higher seasonal variability compared with other income groups (Figure 3.4). They are also more vulnerable to water variability due to limited adaptation capacities (Hallegatte et al. 2016). Even slight changes in the timing of water availability could result in significant economic costs, particularly for subsistence farmers who depend on rainfed agriculture as their primary source of income. For example, subsistence farmers living in the Central American dry corridor were anticipated to experience crop losses of up to 25 percent due to the delayed onset of rainfall in 2023. In contrast, yields among commercial producers were not expected to be affected due to irrigation use (USAID 2023).

INEQUALITIES IN ACCESS TO IRRIGATION

Expansion of irrigation has driven global poverty decline in part by increasing food supplies, putting downward pressure on prices, and by providing livelihoods. As climate change increases the variability of precipitation in both time and space, irrigation holds one of the keys to maintaining stability in local food production and global agricultural markets. However, the benefits and costs of irrigation have not been equally shared, leading to disparities. This section will explore the drivers of these disparities and their resulting consequences.

FIGURE 3.4 Countries with lower income tend to face a higher risk of seasonal variability

Average within-year variability of available water supply by country income group



Source: World Bank analysis based on data from WRI aqueduct.
Note: Seasonal variability measures the average within-year variability of available water supplies, including renewable surface and groundwater. Higher values indicate wider variations of available supplies within a year. The categories are defined as low (0—1), low-medium (1—2), medium (2—3), high (4—5). Bars denote the mean across countries and within each country income group. The inter-quartile range (IQR) denotes the range of values between the bottom 25 and bottom 75 percent of the observations.

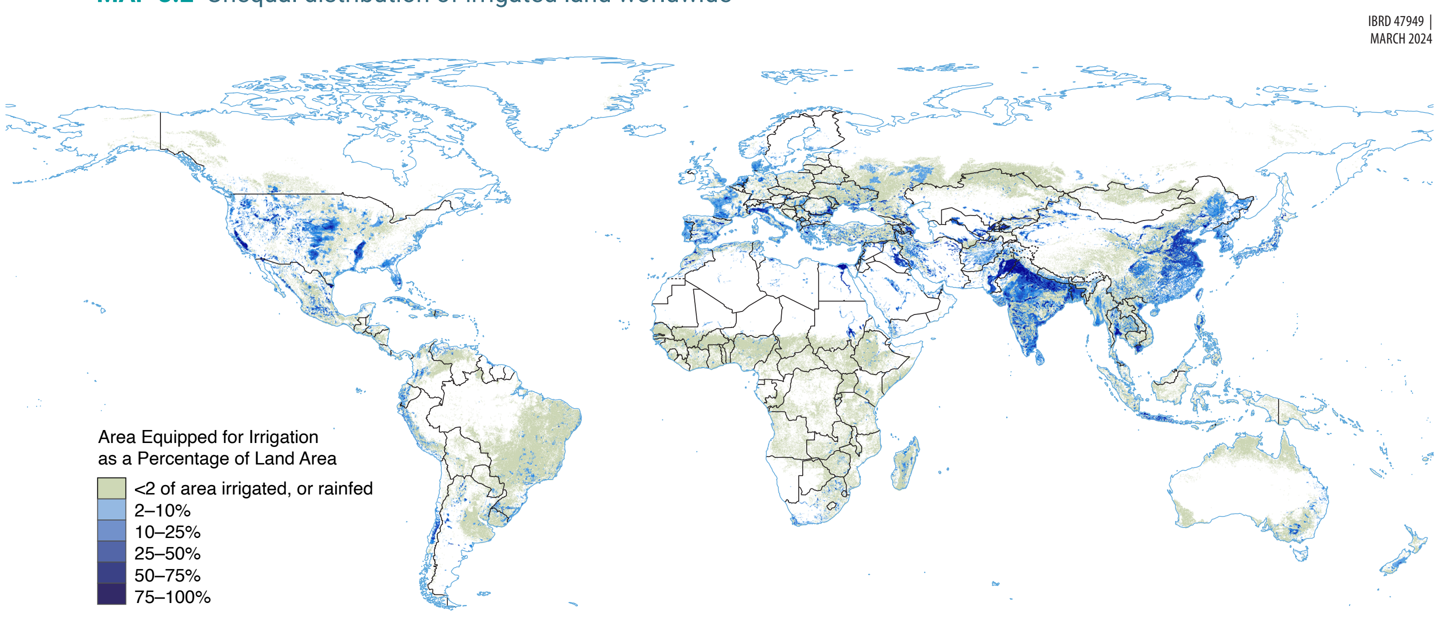
WHO HAS ACCESS TO IRRIGATION?

Over the past 75 years, the global irrigated area has doubled, and the volume of water withdrawn for irrigation has tripled (Wang 2022). The first decades of this expansion were based primarily on public investment in large scale surface irrigation and related infrastructure (for example, dams and canals). Expansion has continued through (mostly) small-scale, farmer-led groundwater development. According to Siebert et al. (2010), groundwater accounted for more than 40 percent of total irrigation water withdrawals by 2010.[1]

Irrigation expansion has not been uniform. Although irrigation is found in almost every country in the world, the majority is highly concentrated in just a few areas, including the Indo-Gangetic Plains of South Asia, the North China Plain, the major river deltas of Southeast Asia, and parts of the United States. India (22 percent), China (21 percent), and the United States (7 percent) alone account for half of the global irrigated area (Zhang et al. 2022). In contrast, Africa, a continent nine times the size of India, has minimal irrigation outside of a few countries, including the Arab Republic of Egypt, Madagascar, South Africa, and Sudan (Map 3.2), despite having access to shallow groundwater and the potential to expand irrigation.

Unequal access to irrigation systems has widened inequalities between those with access and those without access. The expansion of irrigation has positive and negative effects on farmers as producers. On the one hand, it increases productivity and leads to a growth in output, but on the other hand, the decrease in prices can reduce profits. For farmers who have had access to irrigation, the benefits from productivity increase have generally outweighed the price declines (Lipton and Longhurst 1989). However, farmers without irrigation access have experienced only falling prices.

MAP 3.2 Unequal distribution of irrigated land worldwide



Source: Food and Agriculture Organization of the United Nations.
Note: Irrigation is shown as a percent of land area.

Perhaps the most striking illustration of these differential effects can be observed by comparing Asia and Sub-Saharan Africa. Viet Nam serves as a noteworthy example. Along with undertaking land and market reforms, this water-abundant country invested $6.5 billion in irrigation infrastructure from the late 1980s to the early 1990s. With improved rice varieties already available for irrigation, rice yields increased by 50 percent, significantly reducing caloric deficits and transforming the country from a net rice importer to the world's second-largest exporter. Studies suggest that every 5 percent increase in Vietnamese irrigated land reduced poverty by almost 1.3 percent annually, with the largest impact in the poorest areas (Quyen 2019).

In much of Sub-Saharan Africa, low population densities and various other limitations have hindered the growth of irrigation (Box 3.2). As a result, farmers in Sub-Saharan Africa have been unable to reap the direct benefits of irrigation or gain access to high-yielding seeds developed during and after the Green Revolution. Additionally, they have had to compete against imports from irrigated agriculture in other regions of the world. One of the most notable examples is the enduring struggle of many African farmers to compete with Asian imports of rice, a key staple in many African countries.

WHO BENEFITS FROM IRRIGATION?

The benefits of irrigation are not equally distributed even among farmers who gained access to irrigation within a particular country or region. A large literature (see a review by Giordano, Namara, and Bassini 2019) has shown that benefits will vary depending on a variety of factors including irrigation type (for example, surface versus groundwater), location within the system (for example, head end versus tail end), relative land size, access to capital to support complementary investments such as appropriate seeds and fertilizer, and the social strata within communities, such as class and caste structure and so on.

BOX 3.2 Sub-Saharan Africa's untapped agricultural water potential

Surface water suitable for irrigation is more limited in Africa than Asia as are the shallow aquifers which fueled South Asia's groundwater revolution.[2] However, environmental differences are not the only reason Asia's irrigation–expansion, poverty-reduction story has not been repeated in Africa. Differing demographics also played a significant role, a role which is about to change.

In 1950, Africa's population was about half that of Europe and one-fifth of Asia's. By 2020, Africa's population was almost twice that of Europe and one-third of Asia's. By 2100, Africa will have 8 times the population of Europe and almost equal Asia's (Figure B3.2.1 panel a). While the relative size of Africa's population is rapidly increasing, so is its structure. Africa now has the world's highest dependency ratio (= number of children and elderly divided by number of 20–64-year-olds). By 2100, it will have the lowest (Figure B3.2.1 panel b). Africa is today, and will remain for a century, the only world region with a falling dependency ratio. These changes have important implications for African food demand. Less discussed but equally important will be the impacts on African food supply.

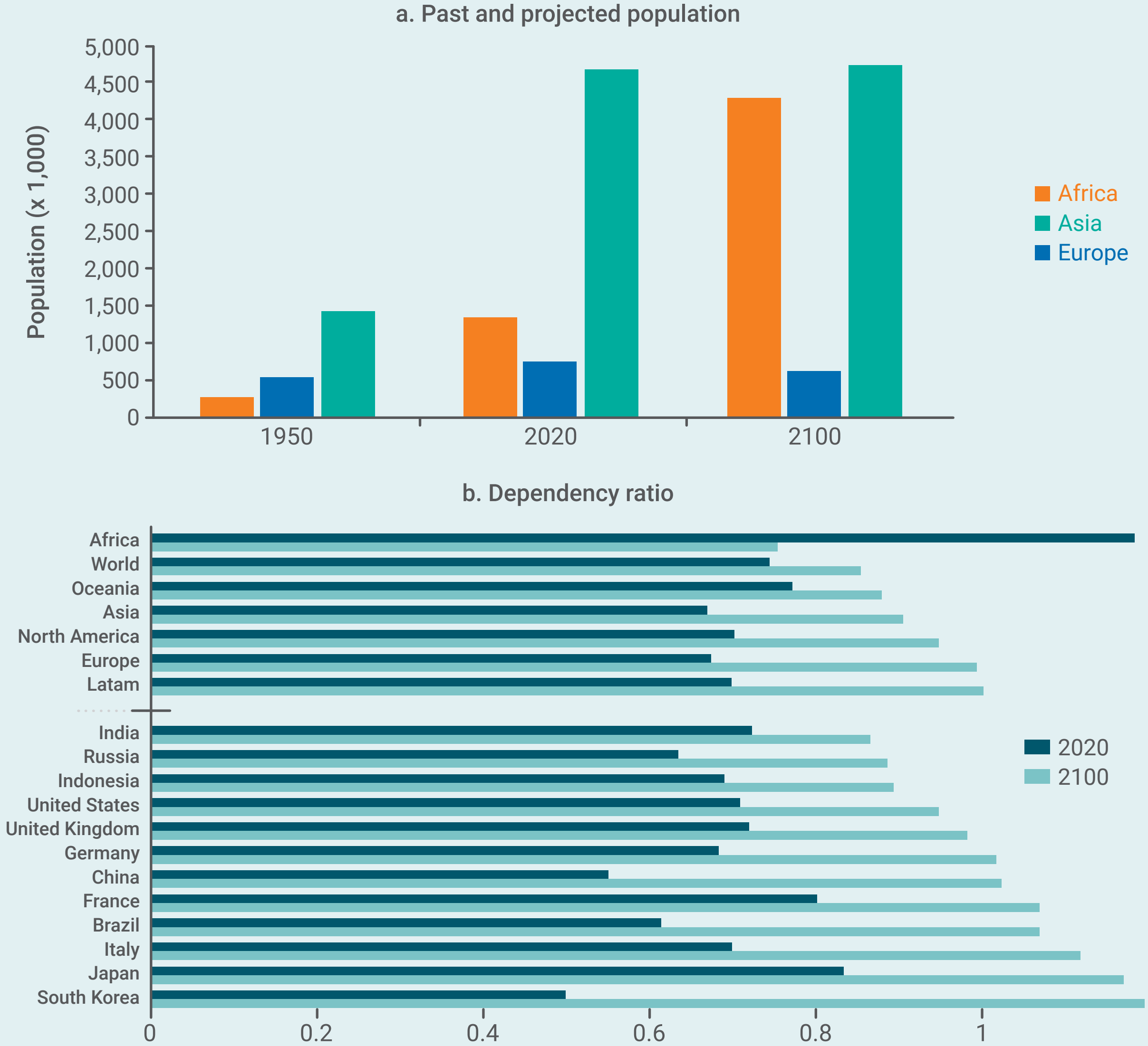
When the Green Revolution was launched in the 1960s, Africa's population was relatively small, and per capita land availability was high. As a result, land was not a key production constraint, and farmers had little

Box continues next page

Box 3.2 *continued*

incentive to invest in or use yield-enhancing intensification technologies such as irrigation (Binswanger and Pingali 1988; Evenson and Gollin 2003; Webb 2009). In much of Asia, the situation was reversed. As a result, the sources of cereal production growth in the two continents differed. Increases in African cereal production were driven as much by area expansion (extension) as by yield increases (intensification). In contrast, rapid cereal production increases in most of Asia were driven almost entirely by yield gains, largely supported by irrigation.

FIGURE B3.2.1 Total population, Europe, Africa, and Asia (1950, 2020, and 2100) and dependency ratios (2020, 2100)



Source: UN Population Division Data Portal.
Note: Cereal production and land use data come from Our World in Data's "Land used for cereal" dataset. Other data come from FAO's "Production: Crops and livestock products" dataset.

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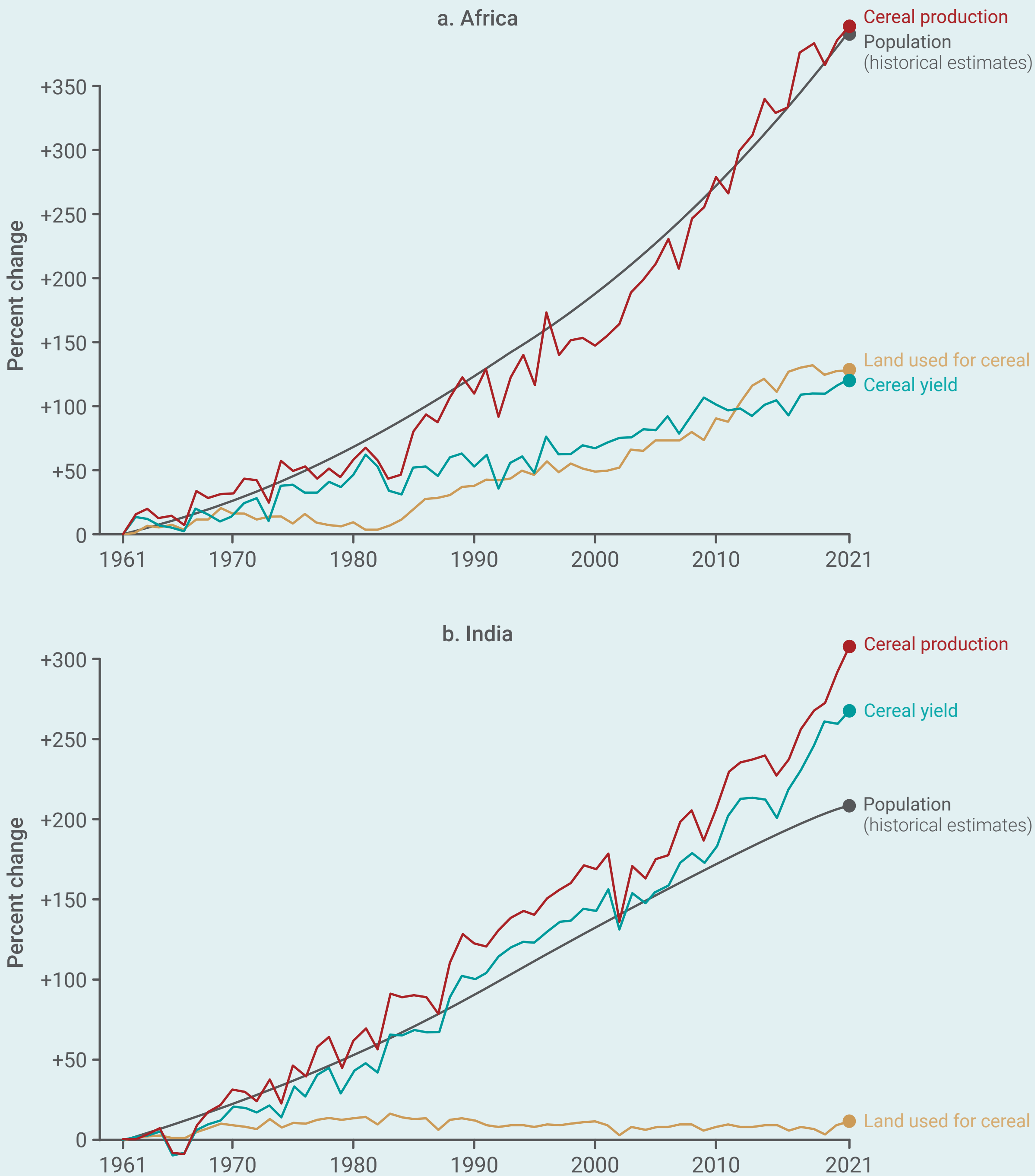
Box 3.2 *continued*

FIGURE B3.2.2 Percent change in cereal production, land use, and population (1961–2022)



Source: Food and Agriculture Organization of the United Nations (2023).
Note: Cereal production and land use data come from Our World in Data's "Land used for cereal" dataset. Other data come from FAO's "Production: Crops and livestock products" dataset.

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Box 3.2 *continued*

This contrast is graphically illustrated in Figure B3.2.2 for the specific case of India, the world's largest irrigating economy.

The situation is rapidly changing. Some regions of Africa have now reached per capita land availability levels similar to those of Asia at the start of the Green Revolution (Otsuka and Kijima 2010). Many others will reach those levels in the coming years and decades. The transition from relative land abundance to scarcity will fundamentally shift the economics and politics of African agricultural intensification. While surface irrigation opportunities in Africa will never rival those in Asia, incentives for some expansion and re-investment in existing surface systems will increase.

Perhaps most importantly in the African context, incentives for long-term investments in the productivity of the continent's extensive rainfed agricultural lands will increase. Africa will not see the pump revolution of South Asia, but areas for privately expanded groundwater do exist (Rodella et al. 2023) along with other opportunities for farmer-led irrigation, such as on-farm ponds, communal river diversions, and green water investments like watershed and soil water management. Additionally, the demand for new technologies, particularly improved seed varieties, will be induced, just as it was during the original Green Revolution. An emerging biotech revolution will drive down costs, making it economic to target so-called orphaned crops common to Africa's highly variable agro-climatic regions.

Asia's economic "miracles" occurred under similar conditions of high population growth and falling dependency ratios. In a twist on Rostow's modernization theory, the conditions now exist for an African "miracle" underpinned by agricultural productivity. Because Africa has the highest number of absolute poor as well as the lowest urbanization rates, the transformation of African agriculture is among the most promising pathways to global poverty reduction. Policies and institutions that encourage investment and equity can accelerate progress.

Source: This box was contributed by Mark Giordano.

Empirical evidence indicates that equity in the distribution of irrigation benefits has paralleled equity in land and water distribution (Sharma, Varma, and Joshi 2008). Equitable distribution of farmland (and by implication, water, which is often distributed based on land ownership) ensures the benefits of irrigation were evenly distributed. In contrast, when land distribution was unequal, public irrigation systems tend to disproportionately benefit farmers with large land holdings. In addition, surface irrigation was associated with greater inequality in the distribution of benefits across farms than lift (groundwater) irrigation. This result was further exacerbated when landholdings were unequal.[3]

The distribution of irrigation benefits is often associated with farm location within systems. Studies show that when systems were not governed to provide similar water deliveries the tail-end farmers receive, substantially less water that the head-end farmers receive. As a result, the income of head-end farmers can be much higher than that of tail-end farmers (Chambers 1988). The head-tail divide in surface irrigation benefits can be attenuated when tail-end farmers can use groundwater to augment water supplies.

Gender is no less important in determining irrigation performance (Zwarteveen 1997; Ray 2007; Van Koppen and Hussain 2007; Domenech and Ringler 2013; Meinzen-Dick, Kovarik, and Quisumbing 2014). Women comprise almost 40 percent of the global agricultural workforce (FAO 2020) and are likely responsible for over half of food production in developing countries (Bhattacharya and Rani 1995; Doss et al. 2018). However, women's access to agricultural water decision-making and resources is often limited by many factors, including access to land, water, labor, capital, credit, technology, and other resources (Molden 2007).

Asayehegn (2012) conducted a study in Ethiopia and found that male-headed households were 38 percent more likely to participate in irrigation than female-headed households, which tended to have fewer laborers and less access to market information. Therefore, although women may have the same potential agricultural productivity as men, unequal access to resources and information inhibits women from fully benefiting from irrigation.

Women are often excluded from irrigation operations and have less access to supporting technologies. Less than 20 percent of landholders globally are women (UN-WOMEN 2012). Studies in Malawi have found that women often pay for new irrigation technologies in cash and, consequently, are often limited in the size of their purchases, unlike men who have greater access to credit (Kamwamba-Mtethiwa et al. 2012). In Kenya, Malawi, Sierra Leone, Uganda, and Zambia, women receive less than 10 percent of the credit awarded to farmers (Squires 2011).

The costs associated with irrigation are often unequally distributed. Construction of dams and reservoirs to support irrigation has been associated with displacement costs that disproportionately fall on the poor. Duflo and Pande (2007) revealed that although irrigation dams increase agriculture production and climate resilience in downstream districts, they significantly increase rural poverty and the vulnerability of agricultural production to rainfall shocks in the districts where they are located. Irrigation also impacts naturally occurring environmental services provided by free-flowing rivers, on which the poor disproportionally rely. For instance, inland and marine fisheries often breed in freshwater-dependent lagoons, which are affected by the changes in water flow caused by irrigation.

INEQUALITIES IN ACCESS TO WATER AND SANITATION SERVICES

Philosophers and economists have long argued that equality of opportunity is key to achieve distributive justice (Arneson 1989; Cohen 1989; Dworkin 1981a, 1981b; Roemer 1998). The idea is that individual's personal talent and efforts should determine their prospects of success in life, rather than circumstances at birth, such as gender, location, race, ethnicity and so on. As discussed in the previous chapter, access to essential services, such as drinking water and sanitation, especially during early stage of life, is crucial for the accumulation of human capital and is therefore fundamental to ensuring equality of opportunity.

Public choices should be made to compensate people for disadvantages related to their circumstances (Roemer 1998). However, access to essential services is far from universal, and households and individuals from less privileged backgrounds are often excluded. This section assesses the extent and trends of inequality in access to drinking water and sanitation.

WHO IS EXCLUDED?

In 2022, some 2.2 billion people worldwide still lacked access to safely managed drinking water, and 3.5 billion people lacked access to safely managed sanitation (Box 3.3). Although disparities in access to drinking water also persist in high-income countries, the challenges are more formidable for low-income and least-developed nations. Only 29 percent of the population in low-income countries has access to safely managed drinking water, compared with 81 percent in upper-middle-income countries and 96 percent in high-income countries (panel a of Figure 3.5). The access gap in sanitation is even larger. Only 24 percent of the population in low-income countries has access to safely managed sanitation, compared with 60 percent in upper-middle-income countries and 91 percent in high-income countries (panel b of Figure 3.5).

Within countries, the poorer population are less like to have access to at least basic water and sanitation services (Figure 3.6).[4] The access gap is especially pronounced in low-income countries, where the richest 20 percent of households have two times the service coverage for at least basic water and four times the service coverage for at least basic sanitation compared with the poorest 20 percent (Figure 3.7).

BOX 3.3 Service ladders for drinking water and sanitation

The World Health Organization (WHO) and the United Nations International Children's Emergency Fund (UNICEF) Joint Monitoring Program (JMP) has provided updated criteria called "service ladders" to benchmark and monitor drinking water and sanitation access globally. The Millenium Development Goals (MDGs) were the targets used between 2000 and 2015 but they only considered basic characteristics of water and sanitation facilities (improved and unimproved). After 2015, the Sustainable Development Goals (SDGs) expanded such criteria based on the quality and reliability of water and sanitation service delivery. The JMP "service delivery ladders" compare the MDG and SDG criteria to show progress on access to water and sanitation services based on SDG targets.

For drinking water, the MDGs targets included "improved" drinking water facilities that could deliver safe water based on their design and construction features. The rest of facilities not meeting such criteria were considered "unimproved". The categories of drinking water access were expanded with the SDGs, based on three levels of quality of service: (1) safely managed water sources, which are improved sources accessible on-premises, available when needed, and free from contamination; (2) basic water sources, which are improved sources for which collection time is not more than 30 minutes for a round trip, including queuing; and (3) limited water sources, which are improved sources for which collection time exceeds 30 minutes for a round trip, including queuing.

Regarding sanitation facilities, the MDG targets defined improved facilities as those intended to hygienically separate excreta from human contact. These include pour-flush or flush toilets connected to piped sewer systems, septic tanks, or pit latrines; pit latrines with slabs (including ventilated pit latrines); and composting toilets. The SDGs added the criteria of quality of service: (1) safely managed sanitation, which represents improved facilities not shared with other households and where excreta are safely disposed of in situ or removed and treated onsite; (2) basic sanitation, referring to improved facilities not shared with other

Box continues next page

Box 3.3 *continued*

households; and (3) limited sanitation, referring to improved facilities shared by two or more households. The service ladders that compare the criteria of MDGs and SDGs for water and sanitation is shown below:

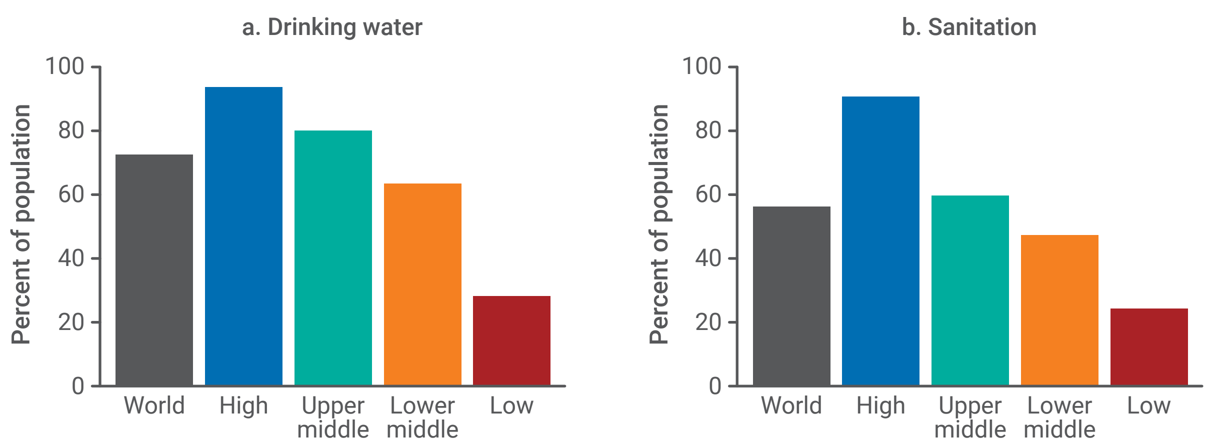
	Level of service	Drinking water
Improved sources	1) Safely managed	Accessible on premises, available when needed and free from faecal and priority chemical contamination
Improved sources	2) Basic	Collection time is not more than 30 minutes for a roundtrip including queuing
Improved sources	3) Limited	Collection time exceeds 30 minutes for a roundtrip including queuing
Unimproved	4) Unimproved	Unprotected dug well or unprotected spring
Unimproved	5) Surface water	Water directly from a river, dam, lake, pond, stream, canal or irrigation canal

	Level of service	Sanitation facility
Improved facilities	1) Safely managed	Not shared with other households and where excreta are safely disposed of in situ or removed and treated offsite
Improved facilities	2) Basic	Not shared with other households
Improved facilities	3) Limited	Shared between two or more households
Unimproved	4) Unimproved	Use of pit latrines without a slab or platform, hanging latrines or bucket latrines
Unimproved	5) Surface water	Disposal of human faeces in fields, forests, bushes, open bodies of water, beaches and other open spaces or with solid waste

In this chapter, data on safely managed services are reported whenever available. When analyzing the access gap between the bottom and top 20 percent wealth quintile, data on "at least basic access" are reported. This is because for many countries wealth index data at the household level are only available from household surveys that provide information on access to at least basic services, rather than safely managed services. At least basic access refers to improved sources that are within 30 minutes roundtrip collection time including queuing (for water) or exclusive to the household (for sanitation), and that could potentially be safely managed. When analyzing the overlap between poverty and lack of access at the district level, data on "improved water and sanitation" are reported. This is because data that distinguish limited, basic, and safely managed services are not available at the district level. Therefore, only improved access can be assessed at the district level.

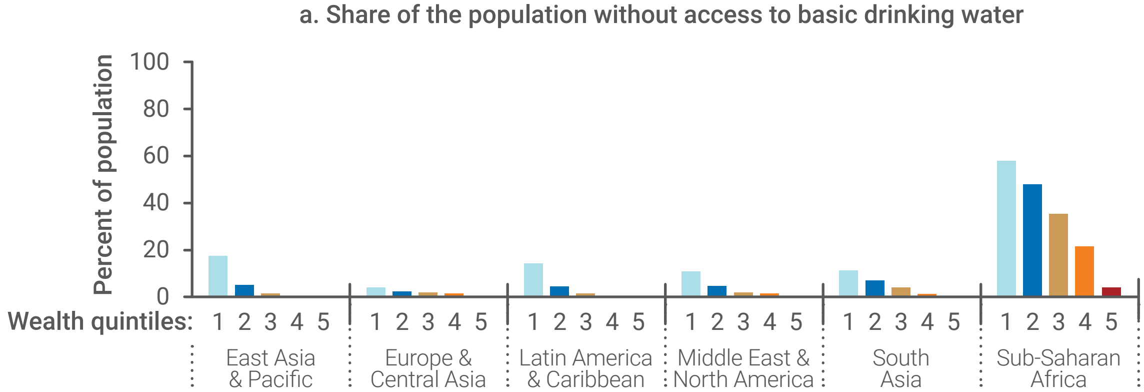
Source: WHO/UNICEF Joint Monitoring Programme (JMP). Accessed April 2024. https://washdata.org.

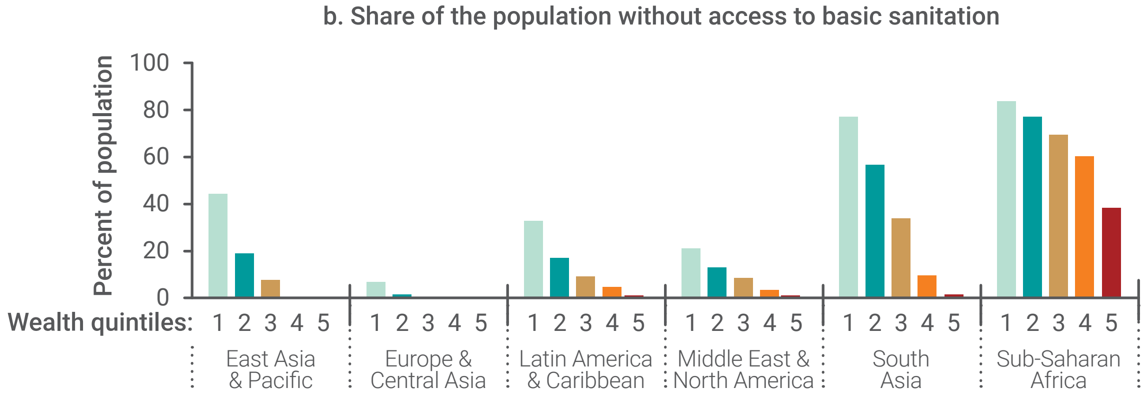
FIGURE 3.5 Large gaps in access to safely managed drinking water and sanitation across country income groups (2022)



Source: WHO UNICEF JMP.
Note: Income groups correspond to the groups the World Bank defined for its fiscal year 2024.

FIGURE 3.6 Access to basic drinking water and sanitation services negatively correlates with wealth quintiles (2022)



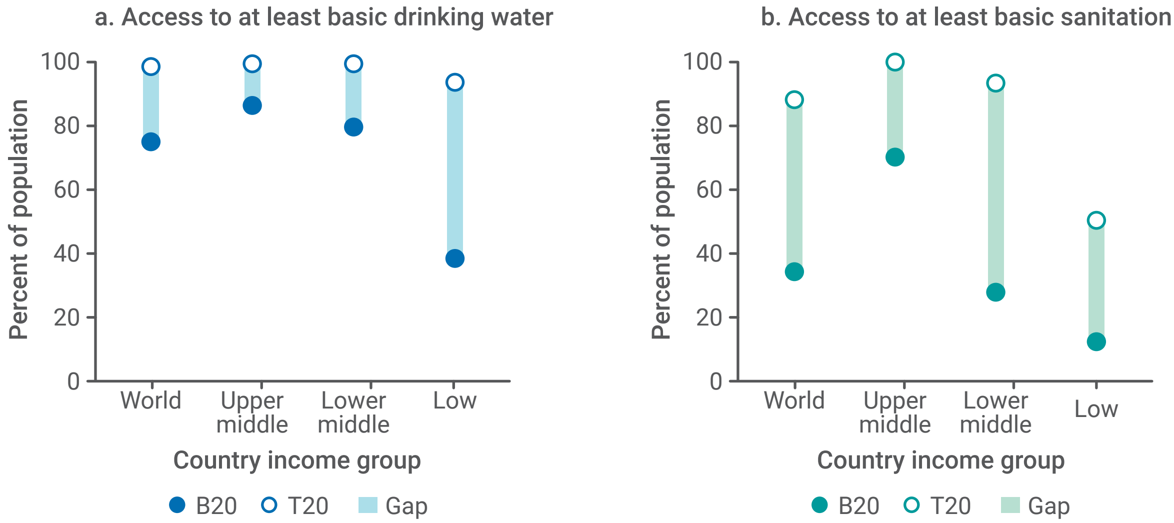


Source: World Bank analysis based on country-level data from WHO/UNICEF JMP.
Note: For the definition of at least basic services, refer to Box 3.3. The analysis covers 91 low-, lower-middle-, and upper-middle-income countries where household wealth index data are available. These 91 countries cover more than 91 percent of the population in low- and lower-middle-income countries, and 31 percent of the population in upper-middle-income countries. The sample notably does not include China. Had the sample included China, the analysis would have covered 82 percent of the population in upper-middle-income countries.

Even where at least basic water sources are available, drinking water is often contaminated (Figure 3.8). Water from improved sources (such as protected springs or pipes) in low- and middle-income countries is often contaminated with *E. coli*, highlighting the need for water treatment in addition to investments in spring protection and piped systems. UNICEF's Multiple Indicator Cluster Survey (collated by Cherukumilli et al. 2022) finds *E. coli* contamination rates over 50 percent for both piped water and protected springs in Sub-Saharan Africa and South Asia.

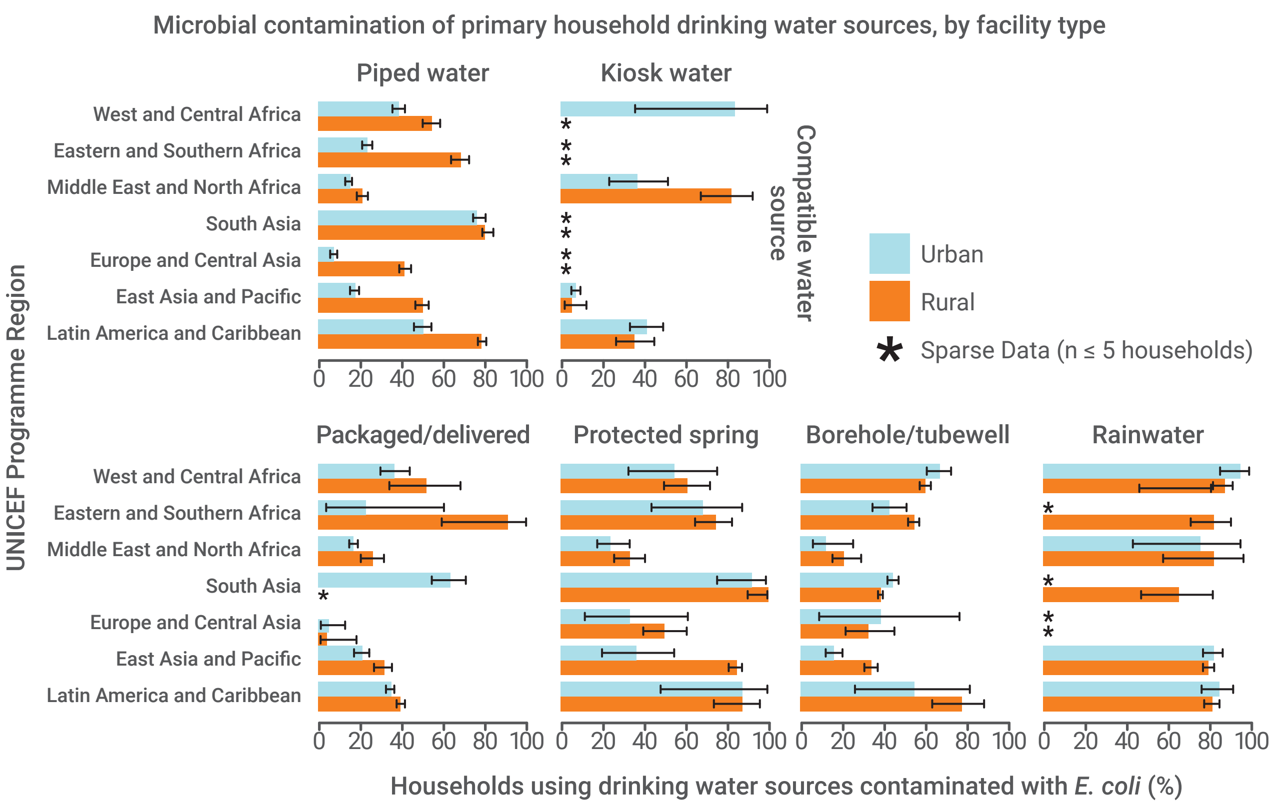
High poverty often overlaps with low access. Worldwide, approximately 450 million people live in high poverty (more than 66 percent of the population live on less than $6.85 per day) and low water access hotspots (less than 33 percent population have access), and approximately 1 billion people live in high poverty and low sanitation access hotspots.[5] These numbers are projected to double by 2050 if current trends continue. Most of these hotspots are in Sub-Saharan Africa, followed by South Asia (Map 3.3).[6]

FIGURE 3.7 Access gap between the bottom and top wealth quintiles is more pronounced in low- and lower-middle-income countries (2022)



Source: World Bank analysis based on country-level data from the WHO/UNICEF JMP for water supply and sanitation.
Note: For the definition of at least basic services, refer to Box 3.3. Household wealth index data are not available for high income countries. The analysis covers 91 low-, lower-middle- and upper-middle-income countries where household wealth index data are available (for further details, refer to the note in Figure 3.6). Gap refers to the access gap between the richest and the poorest 20 percent population. B20 = bottom wealth quintile; T20 = top wealth quintile.

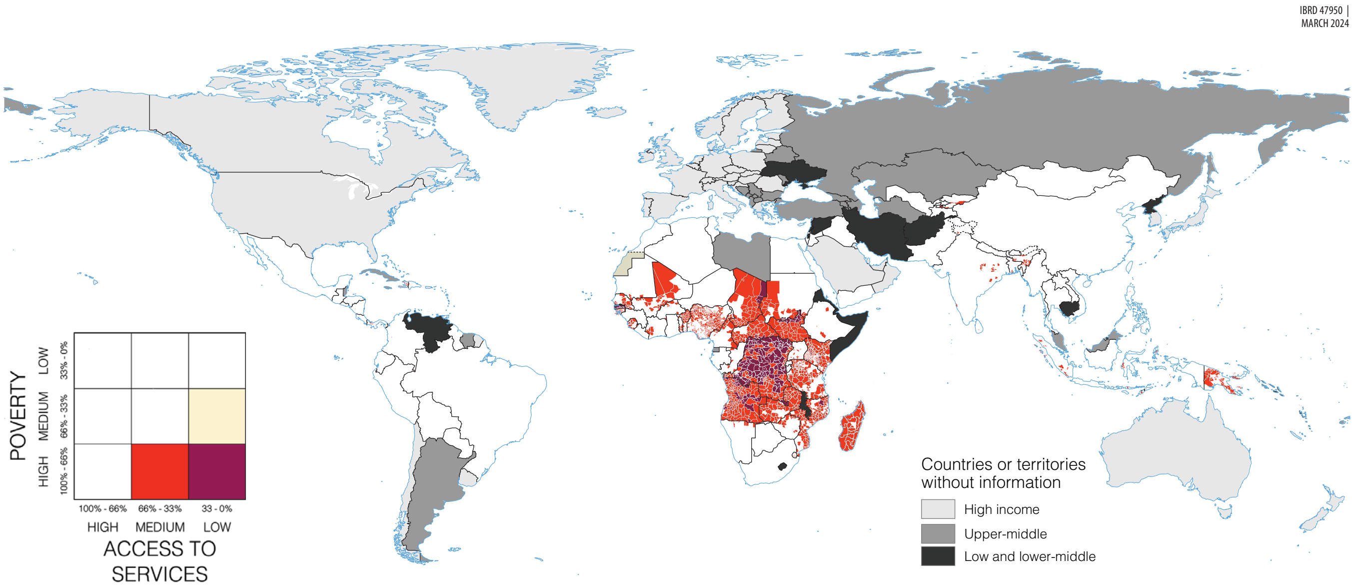
FIGURE 3.8 In both Sub-Saharan Africa and South Asia, well over half of piped water sources are contaminated with *E. coli*



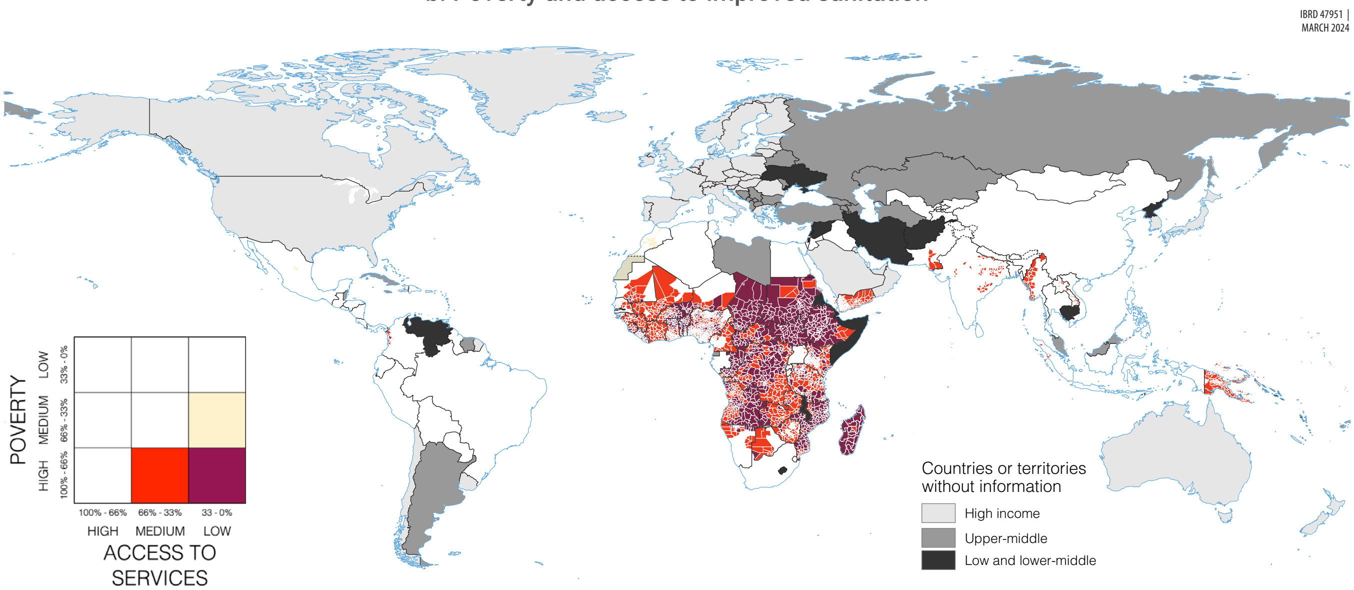
Source: Cherukumilli et al. (2022).

MAP 3.3 Most high-poverty and low-access vulnerability hotspots are in Sub-Saharan Africa (2020)

a. Poverty and access to improved drinking water



b. Poverty and access to improved sanitation



Source: World Bank.

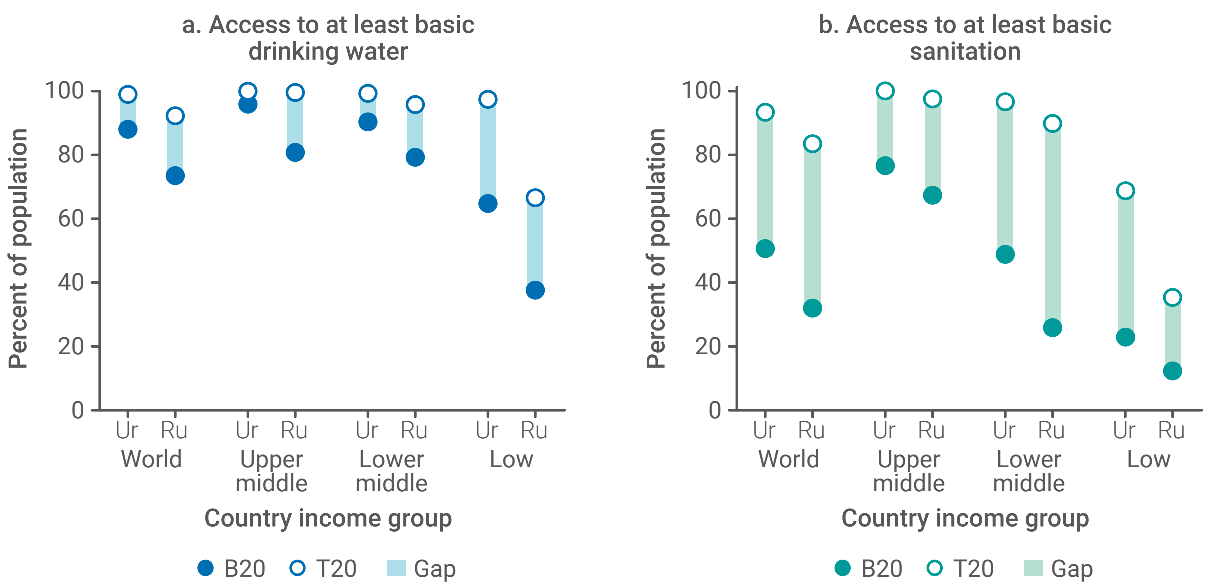
Note: Analysis using poverty data at the state and province level (ADM1) from The Global Subnational Atlas of Poverty (GSAP); Geospatial Poverty Portal, World Bank Group; and municipality and district level (ADM2) access to improved water or sanitation data from Deshpande et al. (2020). Estimates refer to improved water because at the district level estimates that distinguish limited, basic, and safely managed services are not available (see Box 3.3). The information with both poverty and access to services data covers 79 low-, lower-middle- and upper-middle-income countries. Each district (ADM2) receives the poverty rate of its province (ADM1). To identify hotspots, districts are categorized into nine groups based on a combination of three poverty categories (low, medium, high) and three access categories (low, medium, high) to water or sanitation. However, the maps only show three categories: (i) high poverty and low access (shown in dark red), (ii) high poverty and medium access (shown in red), and (iii) medium poverty and low access (shown in yellow). The poverty categories are based on the share of population living below the $6.85 a day poverty line (2017 PPP) in 2019, with low, medium, and high categories defined as below 33 percent, between 33 and 66 percent, and above 66 percent, respectively. The access categories are based on the share of population with access to water or sanitation, with low, medium, and high categories defined as below 33 percent, between 33 and 66 percent, and above 66 percent, respectively. These categories are rare worldwide, with only a few districts falling into in this range, such as those visible in Morocco on the sanitation map.

Location is another important source of inequality. Rural population has lower access to safely managed services in most countries.[7] On average, 8 of 10 people without access to at least basic water services and 7 of 10 without access to at least basic sanitation live in rural areas.[8] Within urban and rural locations, the gap in access between the rich and poor in rural locations is wide. Location matters more for the poor. For at least basic drinking water, in middle-income countries, the urban rich and rural rich enjoy similar level of access, but for those in the poorest bracket, the odds of getting access to at least basic water are three times as high if they live in urban rather than rural locations. For sanitation, the odds are twice as high (Figure 3.9).

Within cities, access is typically lower for informal settlements, or slums (Sinharoy, Pittluck, and Clasen 2019). Six of 10 slum dwellers live close to unsanitary drains, and nearly 4 of 10 have no access to treated water (Pandey and Maurya 2023). The situation is likely to worsen because rapid urbanization has resulted in the migration of people from rural areas to cities, and the proportion of the urban population living in slums had increased to 24 percent or more than 1 billion by 2018 (UN 2022).

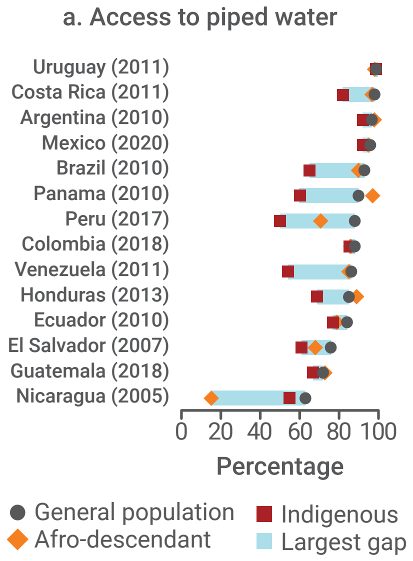
Beyond income and location, other forms of social exclusion are correlated with race, ethnicity, political beliefs, and disability status. These factors often result in marginalized communities facing significant challenges in accessing safe and sufficient water and sanitation services. For example, disparities in access to water supply and sanitation are pronounced among minority ethnic and racial groups. In Latin America and the Caribbean region, on average, 72 percent of the indigenous population have access to piped water, in contrast with 87 percent of the general population (World Bank 2021). The disparity in access to sewage is even larger—only 48 percent of the indigenous population has access to sewage, compared to 71 percent of the general population (Figure 3.10).[9]

FIGURE 3.9 Access gap is large between rural and urban locations particularly for the poor



Source: World Bank analysis based on country-level data from the WHO/UNICEF JMP for water supply and sanitation.
Note: Analysis based on country-level data from WHO/UNICEF Joint Monitoring Programme (JMP). For the definition of at least basic services, refer to Box 3.3. Household wealth index data are not available for high income countries. The analysis covers 91 low-, lower-middle-, and upper-middle-income countries where household wealth index data are available (for further details, refer to the note in Figure 3.5). Gap refers to the access gap between the richest and the poorest 20 percent population. B20 = bottom wealth quintile; T20 = top wealth quintile.

FIGURE 3.10 Access gap is evident between indigenous, Afro-Descendent, and general population groups in selected Latin American countries



Source: World Bank.
Note: Analysis is based on information from the World Bank's LAC Equity Lab (2021) and tabulations of Integrated Public Use Microdata Series (IPUMS), SEDLAC (CEDLAS and the World Bank) and census data from national statistical office websites.

In Pará, a state in Brazil where Afro-descendants comprise 77 percent of the population, only 73 percent has access to piped water, a proportion significantly lower than Brazil's national average of 93 percent. For sanitation, the gap is even wider. Access to sewerage systems in Pará is 29 percent, compared with Brazil's national average of 50 percent (Freire et al. 2018). In Bangladesh, ethnic minorities, representing 1.1 percent of the population, have significantly lower access to improved water and sanitation services compared with the Bengali (Alam 2022). In the Chittagong Hill Tracts of Bangladesh, ethnic communities primarily rely on natural water sources; only 4 percent have access to piped water, and only 7 percent use hygienic latrines (Mahmud et al. 2020).

Similarly, Roma communities across Europe face significant challenges in accessing water and sanitation services. For example, in Romania and Croatia, an alarming 80 percent and 53 percent of the Roma population, respectively, lack access to improved water sources. In Slovakia, most Roma neighborhoods are not connected to piped water sources, and a staggering 83 percent of Roma in Romania lack access to basic sanitation facilities (Kahanec et al. 2020). Furthermore, in the United States, racial disparities are observed, with urban households headed by people of color 34 percent more likely to lack access to piped water compared to their non-Hispanic white peers, and these disparities extend to sanitation facilities as well (Meehan et al. 2020).

Political exclusion may also explain differences in access to water and sanitation services. Ebadi and Damania (forthcoming) find that areas where a significant portion of the population is at risk of political exclusion typically have restricted access to crucial public services such as electricity, water, and sanitation. Communities facing a higher risk of political exclusion tend to have a deficiency in access to water and sanitation services. Involvement in decisions affects how public services get distributed. This particular outcome is consistent regardless of the geographical location of the marginalized communities, which are often in rural regions where providing services is comparatively difficult and expensive. Furthermore, the difference in service accessibility among groups with varying levels of political exclusion risk is not solely due to income disparities. The study finds that as regions become more affluent, the divide in access to services among groups facing different levels of political exclusion risk becomes even more apparent.

Intersectionality exacerbates the challenge—that is, overlapping identity factors converge to deepen the disparities. For instance, in rural Nicaragua, the intersection of being indigenous and living in a rural area compounds the challenges in accessing basic sanitation. While the basic sanitation coverage is 72 percent for the non-indigenous rural population, it drops to 63 percent for indigenous peoples, demonstrating a clear overlap of ethnic and geographical factors leading to increased disparities (World Bank 2016).

THE DYNAMICS OF INEQUALITIES

The Human Opportunity Index (HOI) can be used to evaluate inequalities in access to basic services without having to track the gap in access by each circumstance (predetermined characteristics such as ethnicity, gender, birthplace, or family wealth). The HOI measures inequality-adjusted access rates by "penalizing" countries where access to services is unequally distributed among the population (Box 3.4). The greater the differences, the lower the level of national HOI (Paes de Barros et al. 2008). For example, if the poorer people—who live in rural locations or share a certain personal circumstance beyond their control (for example, race)—are more likely to be excluded, the HOI would be lower than the country's average coverage rate.

The HOI is estimated using household survey estimates by the WHO-UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene (JMP). Given information availability, two circumstances are considered: location (rural versus urban) and wealth.[10] The dissimilarity index measures the dispersion of access across groups by these circumstances (Box 3.4).[11] The greater the dissimilarity index, the greater the degree of inequality for the same level of coverage.

BOX 3.4 The Human Opportunity Index

Paes de Barros et al. (2008), based on Sen (1976), proposed the HOI to evaluate the average coverage of a certain service necessary to progress in life and the inequality of its distribution. The HOI is calculated as:

$$HOI = \bar{p}(1-D)$$

$$D = \frac{1}{2\bar{p}} \sum_{i=1}^{n} \beta_i \,| p_i - \bar{p}|$$

Where D is the dissimilarity index, defined as the weighted average of the opportunity gap—the absolute difference of the group's access rates (p_i) from the average access rate for the population as a whole ($\bar{p}$) and n is the number of circumstances considered. Circumstances are predetermined characteristics likely out of people's control (ethnicity, gender, birthplace, etc.). For example, one group could be the bottom wealth quintile living in rural areas. By construction, the D-index ranges from 0, if there is no inequality at all, to 1, if inequality across groups is extremely high. A positive value indicates that certain population groups have a lower probability of access to the service.

Box continues next page

Box 3.4 *continued*

The HOI can be increased by providing more services to all (the "scale effect"), or by changing people's circumstances, such as migration from rural to urban regions (the "composition effect"), or by distributing services more fairly (the "equalization effect"). Thus, an increase in overall coverage will always improve the HOI, regardless of whether the improvement is disproportionately higher for disadvantaged groups. Second, the HOI increases when the average rate improves for one circumstance group without decreasing coverage rates for the remaining groups. Finally, HOI rewards a reduction in access inequality when the coverage increase is disproportionately higher among disadvantaged groups.

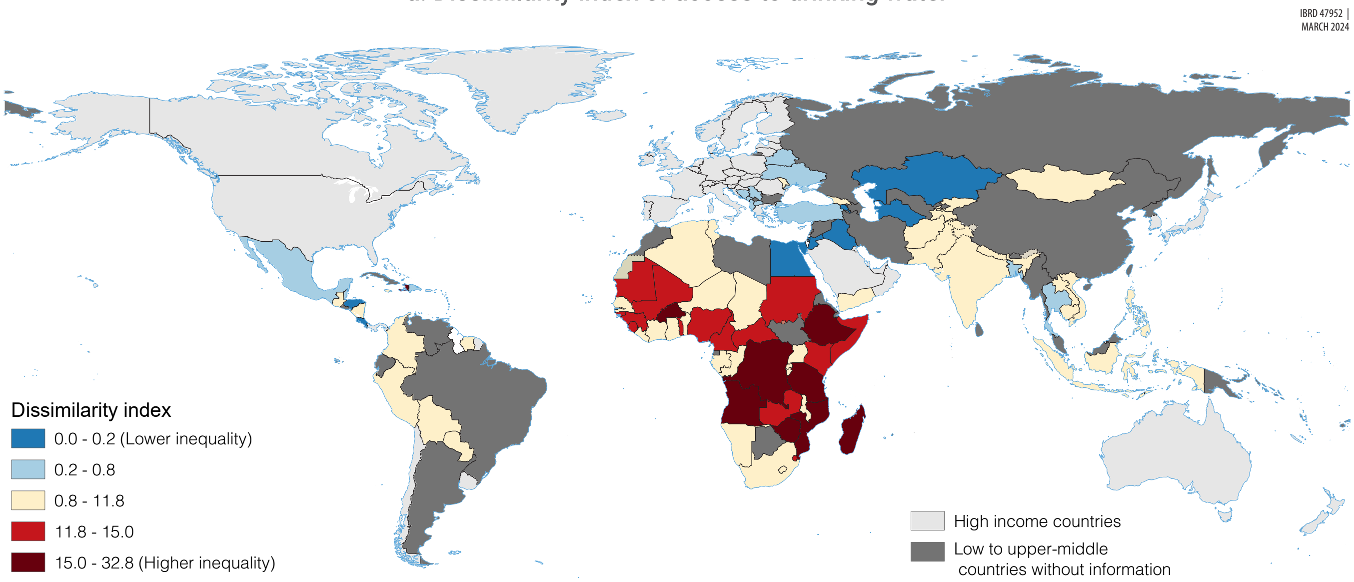
As shown in Map 3.4, the largest opportunity gap as measured by the dissimilarity index is in Sub-Saharan Africa, and the smallest is in Europe and Central Asia. The opportunity gap for access to at least basic sanitation services is twice as high as that for drinking water.[12] There are also marked differences within regions. In Sub-Saharan Africa, the largest dissimilarity index for drinking water is in the Democratic Republic of Congo. Despite having abundant water resources, the country has one of the lowest levels of access and the least equitable access to drinking water. Its dissimilarity index is 18 times as large as that of São Tomé and Príncipe, 12 times as large as that of Malawi, 5 times as large as that of Burundi, 3 times as large as that of Niger, and 2 times as large as that of Ethiopia (panel a of Map 3.4). Madagascar and Chad have the largest opportunity gap in access to at least basic sanitation; Rwanda and South Africa have the smallest (panel b of Map 3.4). Inequality in coverage is low in countries in Latin America and the Caribbean Region, except for Haiti, Bolivia, and Nicaragua (Haiti and Nicaragua regarding water, Haiti and Bolivia regarding sanitation). Countries in East Asia and the Pacific and in South Asia have low- to mid-range levels of inequality.

The good news is that opportunities to have access to water and sanitation services have been improving among all country income groups (Figure 3.10). Low-income countries have registered the fastest progress in expanding coverage of at least basic drinking water, as measured by an annual average increase in HOI of about 1 percentage point during the 2015–22 period. Countries in lower-middle-income countries have made the most significant strides in expanding access to at least basic sanitation, achieving a sustained annual average increase in HOI of about 1.5 percentage points from 2010 to 2022.[13] Improvement in access to sanitation has been slowest in low-income-countries, with an annual average improvement rate in HOI of about 0.4 percentage point, which has remained stagnant since 2010.

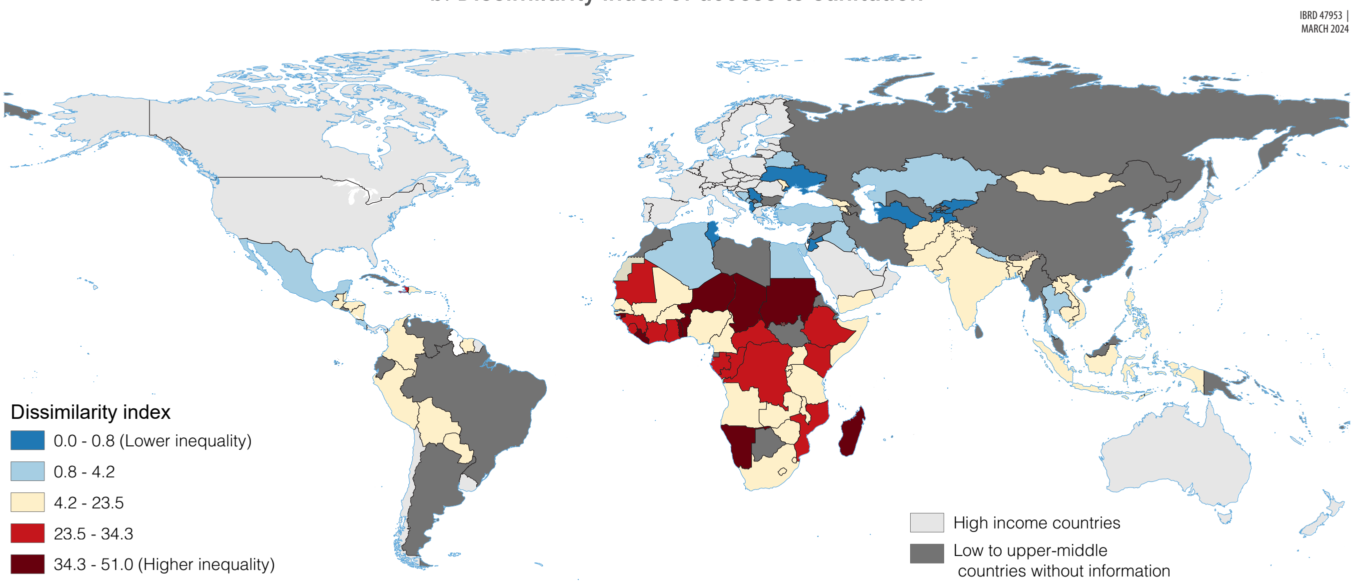
The improvement in HOI is largely driven by an overall increase in coverage rates (the scale effect); the reduction in the dispersion of coverage across groups (the equalization effect) also plays an important role in this improvement (Figure 3.11). For example, from 2015 to 2022, the scale effect contributed to as much as 70 to 80 percent of the improvement in HOI for at least basic water and sanitation across all country income groups. The equalization effect contributed to as much as 15 to 20 percent of the improvement. However, the contribution of the equalization effect has declined since the 2000–05 period in all country income groups, indicating a slowdown in the convergence of access. This decrease is more pronounced for low-income countries. For example, during the 2000–05 period, the equalization effect accounted for 42 percent of the improvement in HOI for at least basic drinking water in low-income countries; it dropped to 19 percent during the 2015–22 period. The equalization effect for at least basic sanitation dropped from 56 to 10 percent.

MAP 3.4 Inequalities in access to at least basic water services are the highest in Sub-Saharan Africa

a. Dissimilarity index of access to drinking water

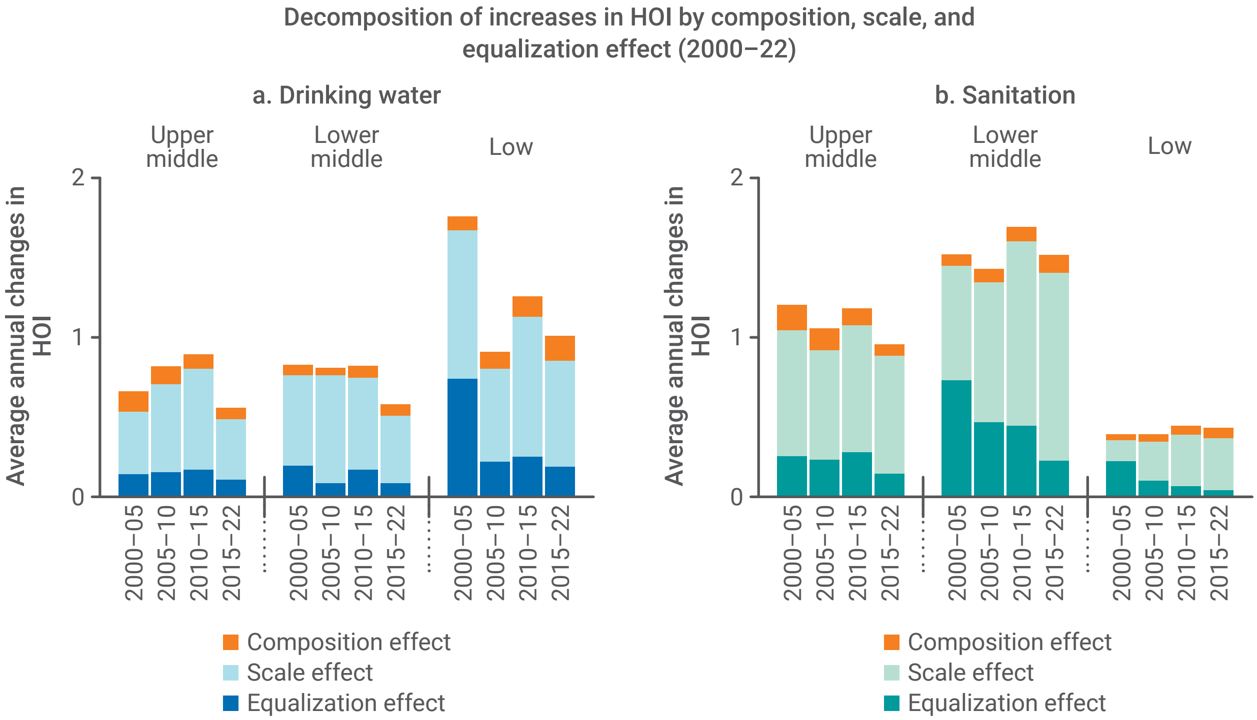


b. Dissimilarity index of access to sanitation



Source: World Bank analysis based on country-level data from WHO-UNICEF JMP.
Note: For the definition of at least basic services, refer to Box 3.3. For the definition of the dissimilarity index, refer to Box 3.4. The index measures inequality across 10 groups defined by urban and rural quintiles. The analysis covers 91 low-, lower-middle-, and upper-middle-income countries where household wealth index data are available (for further details, refer to the note in Figure 3.6). On each map, the five categories correspond to percentiles of the dissimilarity index in the sample: (1) minimum to 10th percentile, (2) 10th to 25th percentile, (3) 25th to 75th percentile, (4) 75th percentile to 90th percentile, and (5) 90th percentile to maximum value.

FIGURE 3.11 Equity in access to at least basic water and sanitation services has increased



Source: World Bank analysis based on country-level data from the WHO/UNICEF JMP.
Note: For the definition of at least basic services, refer to Box 3.3. The analysis covers 91 low-, lower-middle-, and upper-middle-income countries where household wealth index data are available (for further details, refer to the note in Figure 3.6). For definitions of the composition, scale, and equalization effects, refer to Box 3.4. HOI = Human Opportunity Index.

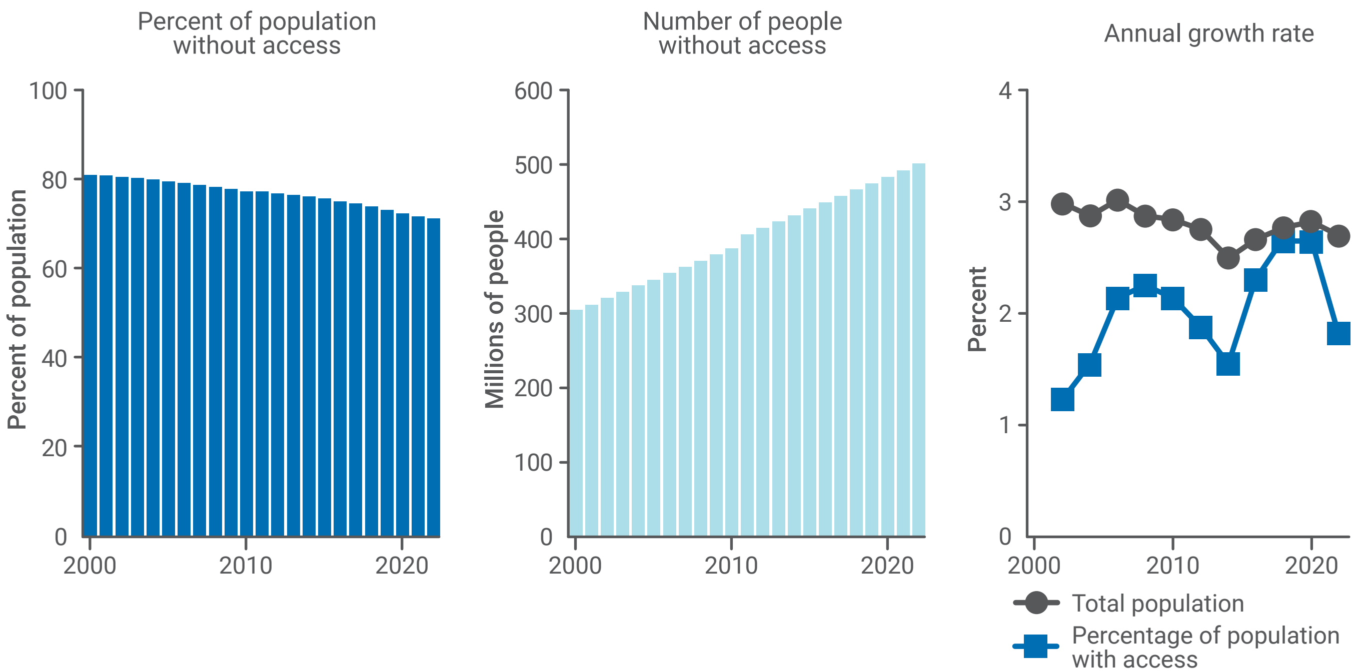
The bad news is that population growth has outpaced the increase in access rate in low-income countries. Since 2000, the annual increase in population has hovered around 2.9 percent, while progress in the share of population with access stands at less than 1.9 percentage points for safely managed drinking water (panel a of Figure 3.12) and 2.4 for basic sanitation (panel b of Figure 3.12). As a result, since 2000, the number of people without access to safely managed drinking water and basic sanitation has increased by 65 percent and 66 percent, or 197 million and 211 million people, respectively (Figure 3.12).

In addition, progress in closing the rural-urban access gap has stagnated in low-income countries, where it has remained constant at about 27 percentage points for safely managed drinking water (panel a of Figure 3.13) and at about 12 percentage points for safely managed sanitation since 2000 (panel b of Figure 3.13).

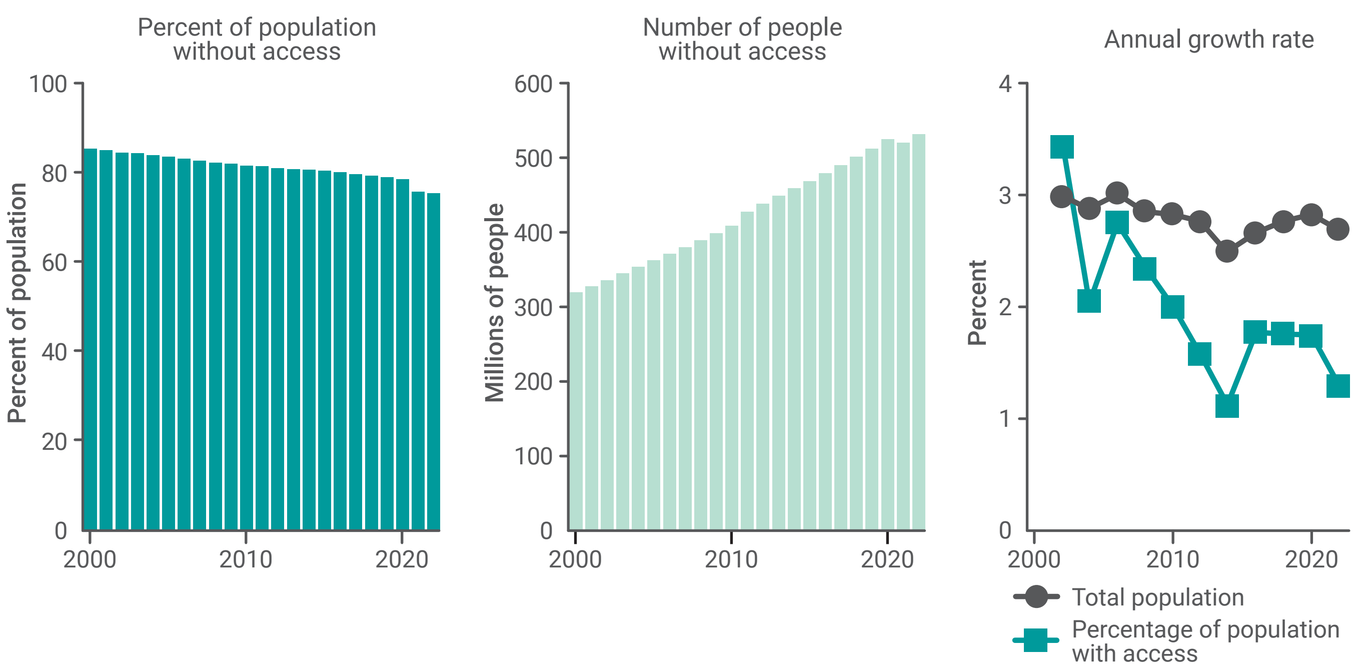
Progress is also lagging in improving access to water and sanitation services at schools and health facilities, particularly in low-income countries where the access rate remains meager. Less than 50 percent of schools (panel a of Figure 3.14) and less than 75 percent of health facilities in low-income countries have access to water (panel b of Figure 3.14). Less than 75 percent of schools and health facilities have access to sanitation (Figure 3.14). For schools, access to water services increased from 40 to 54 percent, and access to sanitation facilities increased from 60 to 75 percent. In lower-middle-income countries, significant achievement was made in improving access to sanitation at schools. Some progress was also made in improving access to sanitation in health facilities, which increased from 60 to 70 percent. However, access to water services in health facilities has remained stagnant.

FIGURE 3.12 In low-income countries the number of people without access to safely managed drinking water and sanitation services continues to increase each year since 2000

a. Drinking water

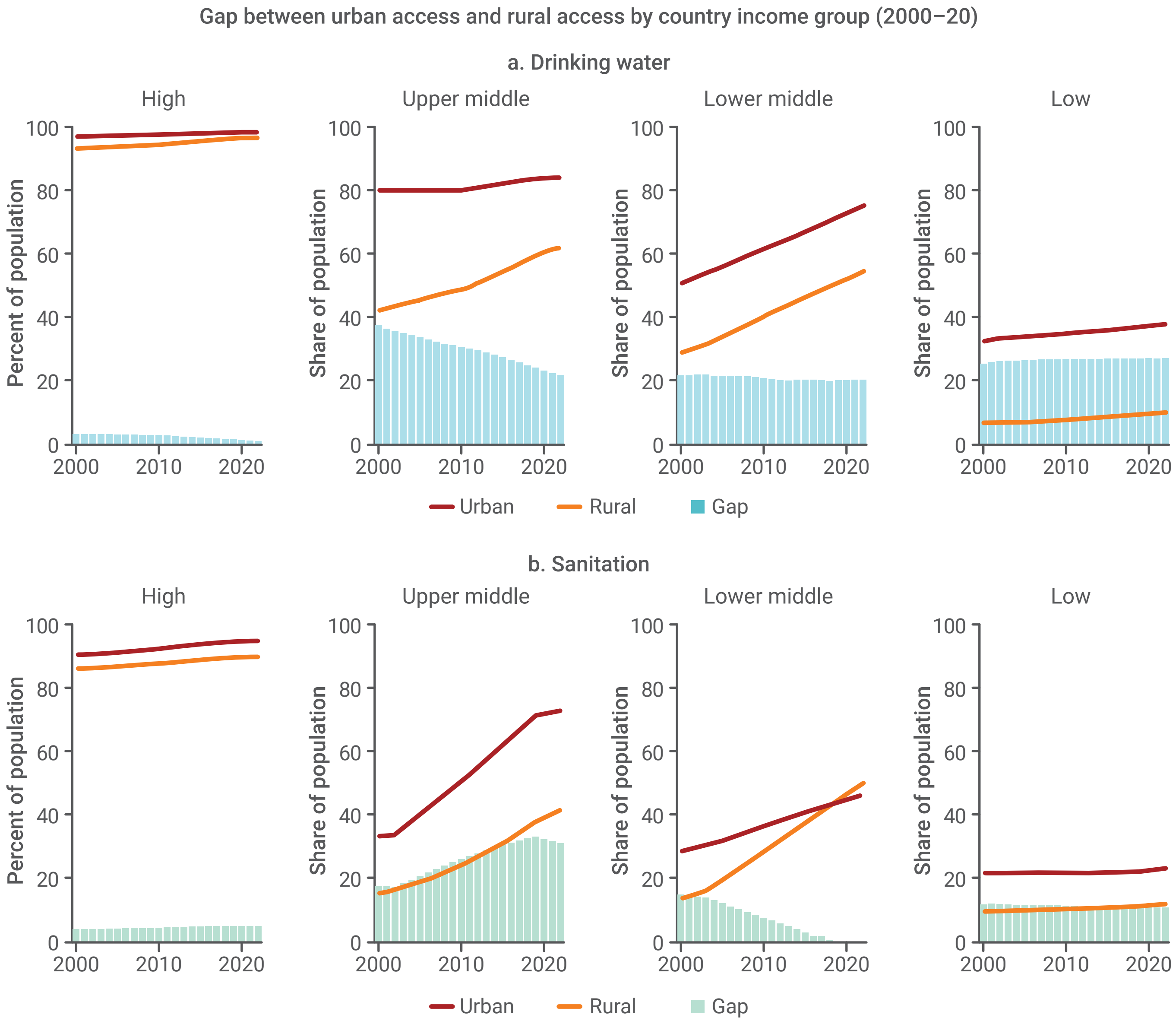


b. Sanitation



Source: WHO UNICEF JMP.
Note: The first column presents the share of the population without access to safely managed drinking water (panel a) and sanitation (panel b) services. The second column presents the number of people (millions) without access to the respective services. The third column presents the annual growth rate in the total population and the share of the population with access to the respective services.

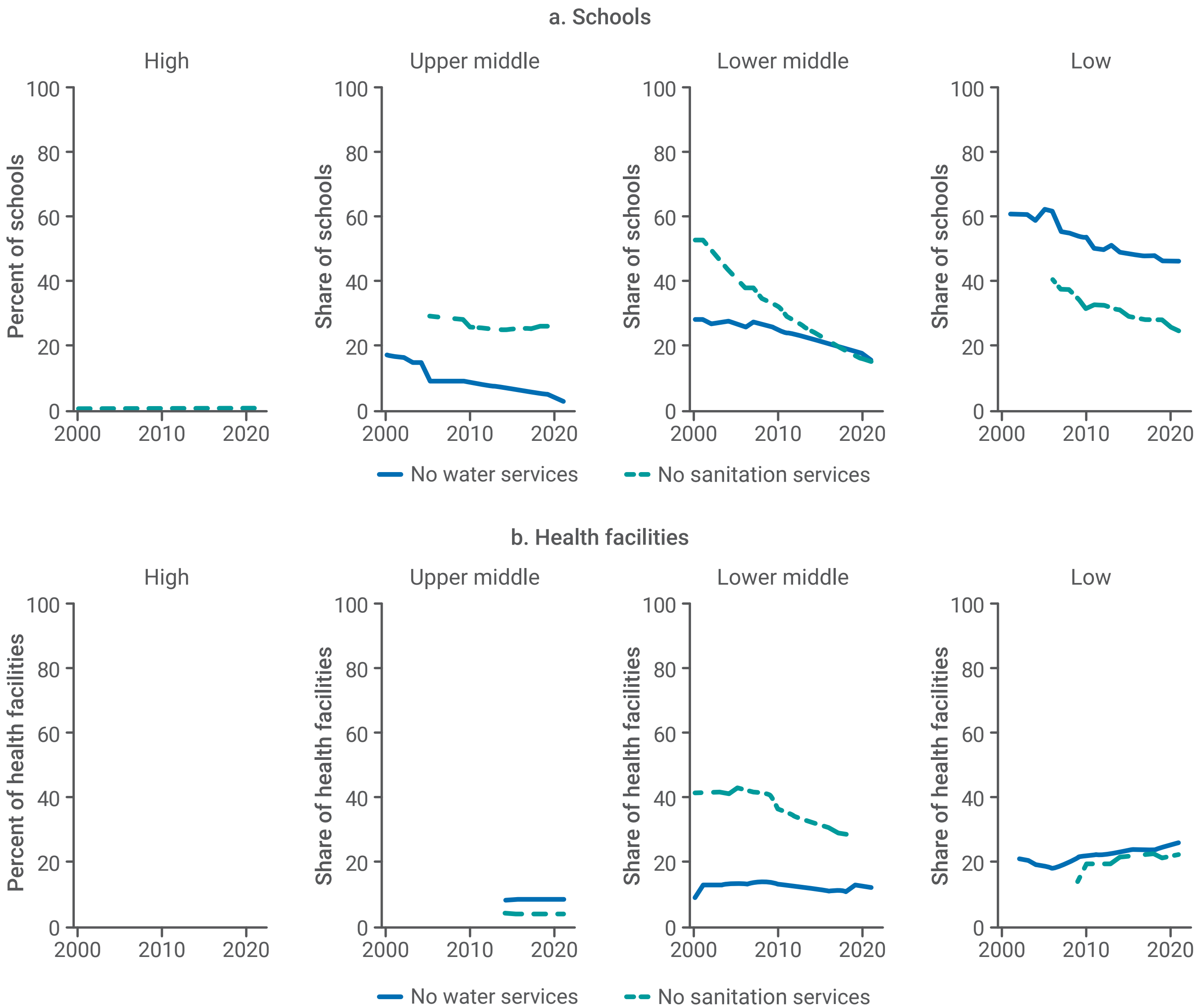
FIGURE 3.13 Progress in closing the rural-urban access gap has stagnated in low-income countries



Source: World Bank analysis based on country-level data from the WHO-UNICEF JMP.
Note: The bars indicate the gap in percentage points between the access rates of urban and rural population.

Inequality in relation to water access can also be driven by quality, in addition to by access. Current global water indicators focus on the physical access to water infrastructure. These are useful and necessary metrics, but they do not tell whether water service delivery is reliable and sufficient for basic needs. The Individual Water Insecurity Experiences (IWISE) scales implemented by the Gallup World Poll in nationally representative samples in 38 countries in 2020 and 2022 is an attempt to address this gap. The WISE scale, which is based on household and individual surveys, measures universal experiences of water insecurity. Respondents are asked to rate whether they have experienced water insecurity based on self-assessment of experiences in the availability, accessibility, usability, and reliability of water for meeting basic needs (see Rosinger and Young [2020] for more details).

FIGURE 3.14 Schools and health facilities lack access to water and sanitation particularly in lower-middle- and low-income countries

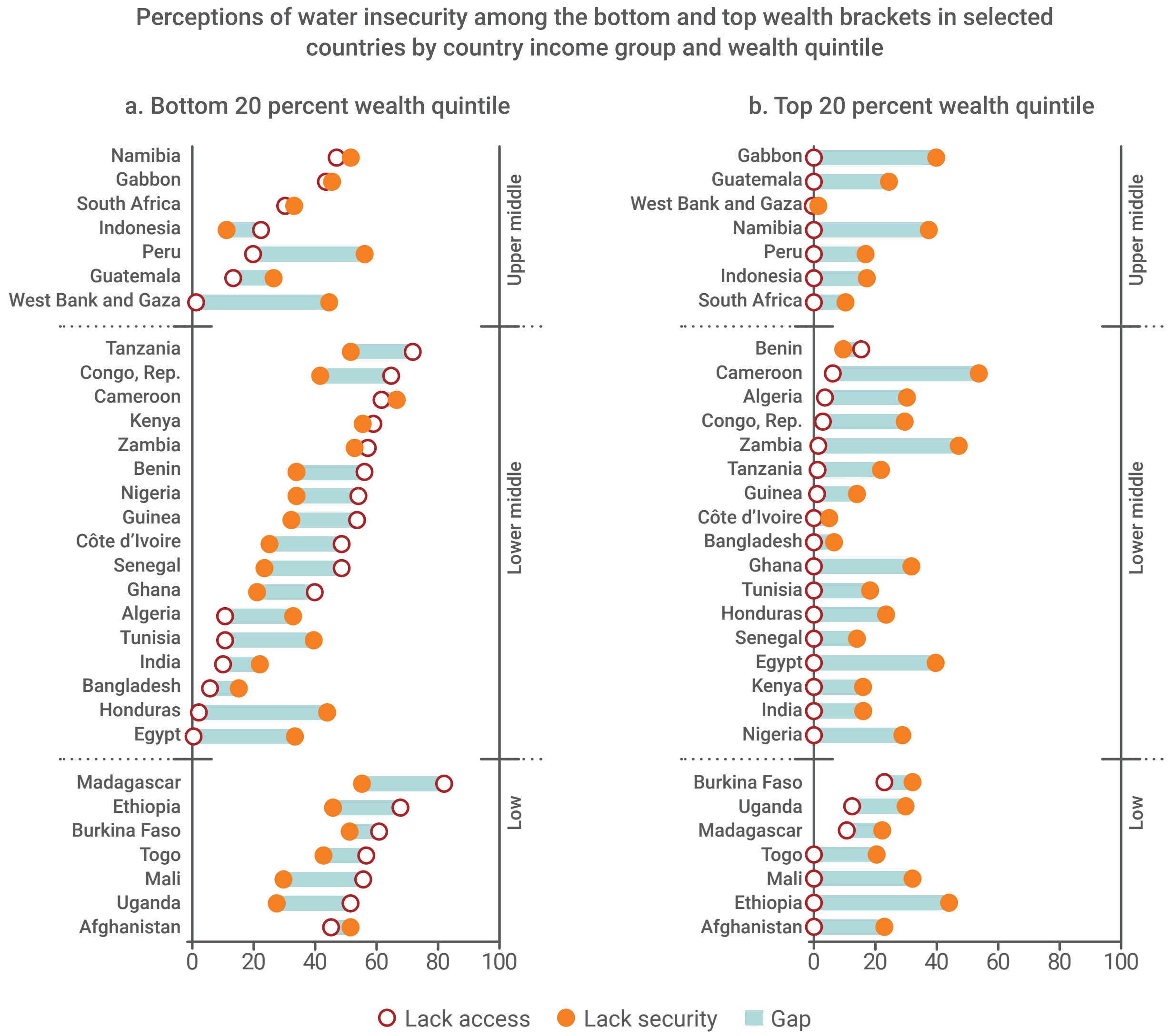


Source: WHO UNICEF JMP.
Note: "No service" refers to the absence of facilities or having unimproved facilities. Gaps in the series indicate a lack of available information. For high-income countries, no information on health facilities is available.

For middle-income countries, and for the top 20 percent population, issues related to water availability and reliability exacerbate water insecurity. A comparison of the WISE scale and the access to at least basic drinking water from JMP for selected countries shows that the proportion of people reported to have experienced moderate-to-high water insecurity is much higher than the proportion of households not using basic drinking water infrastructure among the top 20 percent of the wealth bracket in almost all countries for which data are available (panel b of Figure 3.15). For example, in Cameroon, less than 6 percent of the population in the top wealth quintile had no access to at least basic drinking water, but more than 60 percent of the people in this group reported moderate-to-high water insecurity.

The perception of water insecurity among the population in the bottom 20 percent wealth bracket is not clear-cut (panel a of Figure 3.15). In upper-middle-income countries, the proportion of people who reported moderate-to-high water insecurity is higher than the proportion without access to at least basic water; the opposite is observed in low-income countries. There is no consistent pattern among lower-middle-income countries; however, it appears access is a more pressing issue where the access rate is lower than 60 percent.

FIGURE 3.15 Issues with quality of water services can exacerbate water insecurity



Source: World Bank.
Note: Estimates are based on country-level data from WHO-UNICEF (JMP) and the WISE scale from Northwestern University's Institute of Policy Research. The WISE scale measures the proportion of adults who experience water insecurity. It comprises 12 questions regarding the availability, access, acceptability, and safety or stability of water for basic daily needs . Responses are recorded using a scale of never (0 times), rarely (1–2 times), sometimes (3–10 times), often (11–20 times), and always (more than 20 times). A score of 0 is assigned to "never," 1 to "rarely," and 2 to "sometimes," while both "often" and "always" are scored as 3. The total score ranges from 0 to 36, with higher scores indicating greater water insecurity. A score of 12 or higher is considered as water insecure.

CONCLUDING REMARKS

Water security challenges in developing countries are increasing with population growth, urbanization, and climate change. These challenges are compounded by unequal access to irrigation and large disparities in global access to water and sanitation services. Although significant strides have been made to close the access gap in water supply and sanitation, access rates in low-income countries remain the lowest and the number of people without access to water and sanitation services continues to increase each year. Implementing targeted interventions in these communities is critical to prevent intergenerational poverty due to poor access to safe drinking water and safe sanitation. In a world of increasing water scarcity, the future of irrigation will also have to depart from its past. The final chapter of this report will address policy responses to the issues discussed.

NOTES

1 Post–war large-scale surface irrigation was first developed where hydrologic conditions for storage and distribution were suitable, and the climate was most favorable to agriculture. As surface supplies for additional expansion became limited, and pumping costs dropped starting in the 1950s and 1960s, farmers increased their groundwater use. The groundwater expansion shifted to previously unirrigated regions with limited surface water but shallow aquifers. Now, regions with aquifers, sometimes hundreds of meters deep, can be accessed, often unsustainably and at a high energy cost.

2 According to a recent Africa-wide distributed assessment of groundwater irrigation potential, it was estimated that about 42 million hectares of land across the continent could be sustainably developed for irrigation. This is 20 times more than the current actual levels and would cover approximately 19% of the cropland (Altchenko and Villholth 2015).

3 Land holdings are related to water allocations in surface systems, so those with more land get more water. Access to groundwater within a surface system can offset those inequalities because groundwater tends to be more "egalitarian" than surface water, which is limited to particular locations and is allocated by the state.

4 Wealth quintile information is not available for safely managed services. Refer to Box 3.3.

5 High-poverty and low-access vulnerability hotspots are districts and municipalities where, in 2020, more than 66 percent of the population lived on less than $6.85 a day (2017 PPP), and less than 66 percent had access to improved water or improved sanitation. Poverty estimates are at the state and province levels. The poverty rate of a district (municipality) is the rate of its province (state). Estimates refer to improved water because, at the district level, estimates that distinguish limited, basic, and safely managed services are not available (see Box 3.3).

6 In 2020, analysis in this report identified 1,720 high-poverty and low-access vulnerability hotspots. About 90 percent of the people in these hotspots were living in Sub-Saharan Africa, 7 percent in South Asia, 2 percent in East Asia and the Pacific, 1 percent in Latin America and the Caribbean, and less than 1 percent in Europe and Central Asia and in the Middle East and North Africa. Of these hotspots, 262 had access to improved water below 33 percent, and all but a handful were located in Sub-Saharan Africa. As for sanitation, there were twice as many hotspots (3,490) where 1 billion people were living, with 81 percent living in Sub-Saharan Africa, 12 percent in South Asia, 4 percent in East Asia and the Pacific, 3 percent in the Middle East and North Africa, and 1 percent in Latin America and the Caribbean.

7 In 2022, access to safely managed drinking water was higher in urban areas in 80 percent of countries, while access to safely managed sanitation was higher in urban areas in 60 percent of countries. When access is higher in rural areas, the proportion is close to that in urban areas. For example, in Bhutan, access to safely managed drinking water in urban areas is 54 percent and in rural areas is 59 percent. In Bangladesh, access to safely managed sanitation in urban areas is 29 percent and in rural areas is 32 percent.

8 For safely managed services, the gap between urban and rural areas is narrower, stressing the challenge of providing safely managed services even in urban areas. On average, 6 of 10 people without access to safely managed water services and 5 of 10 without safely managed sanitation live in rural areas.

9 Marginalized communities are often overrepresented among the poor. However, limitations in available data for most of the examples presented in this section preclude a more detailed analysis of exclusion based on income versus exclusion based on factors such as race, ethnicity, and other demographics.

10 The two circumstances result in 10 groups: five quintiles in rural areas and five quintiles in urban areas. The dissimilarity index measures the inequality across the groups defined both by location and wealth.

11 An important caveat for making cross-country comparisons of inequalities is that the HOI provides only a lower bound estimate of the inequalities because it considers only measurable circumstances for which data are available. If the calculation included more circumstances, the inequality-adjusted access rate would be lower in certain countries.

12 For access to at least basic water services, the average dissimilarity index across countries is 6.6 (median = 4.7; inter-quartile range = 0.8 to 11.8). For sanitation, the average is 15.6 (median = 12.9; inter-quartile range = 4.2 to 23.5).

13 The HOI in high-income countries also increased, and the share of the equity effect is stable.

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Hydro-Climatic Extremes and their Impacts

CHAPTER 4

"The health of our waters is the principal measure of how we live on the land."

Luna Leopold

CHAPTER 4

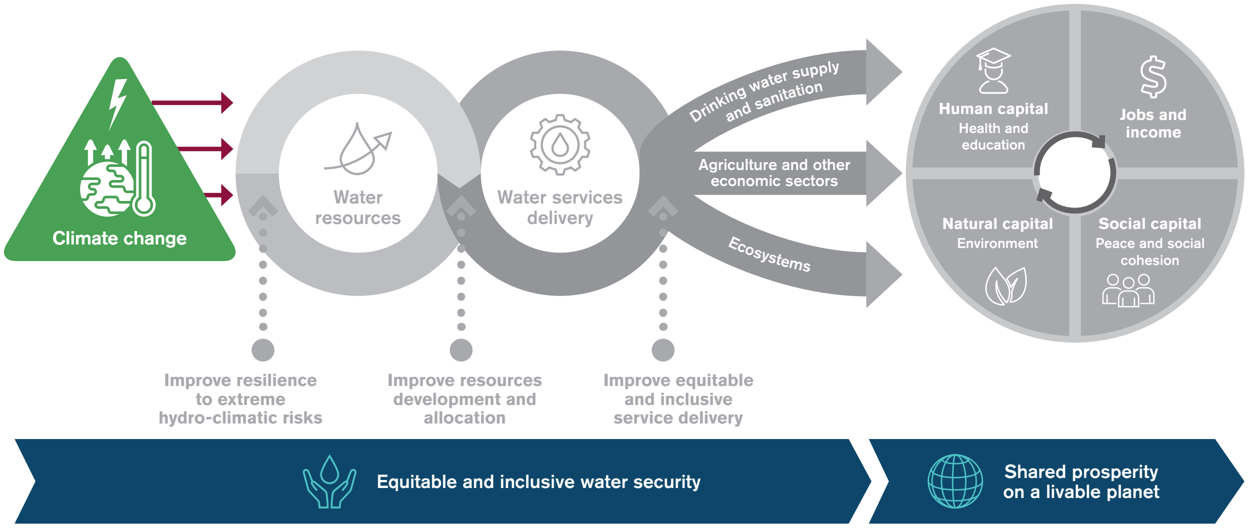
KEY MESSAGES AND FINDINGS

- Climate change will exacerbate water risks worldwide, as rising temperatures lead to more frequent and extreme weather events, such as droughts and floods. Developing countries and the poor population will suffer more because they have fewer coping resources and higher vulnerability.
- Between 2000 and 2021, middle- and low-income countries have had a significantly higher share of land affected by droughts, and experienced higher intensity of droughts than high-income countries.
- Between 2000 and 2021, middle-income countries are more exposed to high flood risks, while low-income countries experienced longer-lasting floods than high income countries. Within countries, in urban areas, the poor are disproportionately at risk from flooding.
- Droughts and floods can exacerbate poverty and inequality. The cumulative and interrelated impact of water shocks on the income, education, and health can push the vulnerable population into poverty and entrapment.

Climate change will exacerbate water risks worldwide, as rising temperatures lead to more frequent and extreme weather events, including floods and droughts. Experts across business, academia, government, civil society, and the international community have ranked extreme weather as the most likely risk to materially impact the world in 2024, and over the next decade (WEF 2024). Due to their relatively unprecedented nature, these extreme water risks can have profound effects and economic shocks on even a wealthy society. In 2023, there were 28 ">billion dollar" extreme weather events that cost the US economy almost $100 billion in damages (NCEI 2024). Developing countries suffer even more because they have fewer coping resources and higher vulnerability.

This chapter explores the effects of droughts and floods on shared prosperity (Figure 4.1). It uses the latest scientific literature and additional analysis to highlight their frequency and geographical prevalence on a global scale, focusing on the impacts in developing countries and the poorest in all societies. It explains why the poorest are often the hardest hit when water-related disasters occur and what makes them especially vulnerable in the short and long term. These disasters multiply the threat to the poor and can push more into poverty, threatening shared prosperity and poverty reduction goals (Hallegatte, 2016). These impacts are illustrated with examples showing the estimated effects of hydro-climatic extremes on the four building blocks of the prosperity for vulnerable groups.

FIGURE 4.1 Hydro-climatic risks threaten the goal of shared prosperity on a livable planet



Source: World Bank.
Note: Water security is defined as the availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems, and production, coupled with an acceptable level of water-related risks to people, environments and economies (Grey and Sadoff 2007). Water services include irrigation, water supply, and sanitation.

DROUGHTS: THE LONG SHADOW

WHO IS AFFECTED?

Water deficits and droughts (Box 4.1) can occur anywhere but are more common in particular regions. In these regions, regional climate, local geography, and land uses combine to increase the chances and impact of drought.

The semi-arid tropics climate zone is particularly drought-prone and spans 48 developing countries. These countries are in Southeast Asia, Sub-Saharan Africa, and a few locations in Latin America. Semi-arid tropics areas are characterized by dry seasons, irregular rainfall, and nutrient-poor soils. In these areas, key subsistence crops like sorghum, millet, and legumes are crucial for local populations. However, environmental stresses, particularly extreme temperatures, drought, and salinity, significantly limit agricultural productivity in these regions (Krishnamurthy et al. 2011).

There has been a significant increase in drought duration, impacted area, and severity in global grain production areas. This trend is most pronounced in developing countries and regions, which are more susceptible to extreme droughts and experience more crop losses (Wang et al. 2018). Another study has shown that drought coincides with high poverty levels in 15 major farming systems, especially those in the Sahel, South Asia, and eastern and southern Africa (Hyman et al. 2008). These areas are affected by frequent drought occurrences and are populated by the world's poorest and most vulnerable farmers.

BOX 4.1 What is drought?

Drought is a general term given to a severe and prolonged lack, or deficit, of water for a specific need, whether for plants, humans, or something else (Yuan and Wood 2013). The term can refer to a lack of water at any point in the water cycle, leading to many definitions of drought. The definition depends on where the deficit occurs and what the specific need for the water is. For example, a lack of rainfall, or precipitation, is called a meteorological drought. This type of drought can lead to a hydrological drought, when river flow diminishes significantly, and water stored in the landscape is used up. It can also lead to agricultural or environmental drought, when the water in soil required to keep plants growing and healthy is lacking. Finally, it can also lead to socioeconomic drought, when society and the economy suffer major impacts.

Meteorological droughts (rainfall deficits) have not substantially changed globally in the last 120 years; however, agricultural, and ecological droughts due to increased water demand from the atmosphere have grown more severe (Vicente-Serrano et al. 2022). This atmospheric evaporative demand (AED) is the part of the water cycle where water returns to the atmosphere. A positive AED causes evapotranspiration, the loss of water from the soil both by evaporation and by transpiration from the plants growing on it. AED is driven mainly by temperature increases. So, even with sufficient rainfall for plants, an increase in AED may lead to drought.

Droughts occur over multiple timescales ranging from weeks to years. If they are especially long, they are called mega-droughts. An example is the Australian "millennium drought," which lasted from 1996 to 2010. It began during an El Niño event and ended with a La Niña event, both large-scale climatic events related to ocean temperature.

This report defines droughts using the Standardized Precipitation Evapotranspiration Index (SPEI) from the University of East Anglia Climatic Research Unit's (CRU) dataset. The index captures deviations from long-term averages both in precipitation and in temperature (for temperature by using potential evapotranspiration as an estimate of AED). SPEI values are standardized, making comparison across space and time possible. A SPEI value of -1,-2, and -3 indicates deficits of about 1, 2, and 3 standard deviations from the local long-term average, respectively. To estimate the occurrence of droughts, the SPEI is calculated at the grid-cell level for every month between 2000 and 2021. A grid-cell is considered to be under drought when the SPEI is below -1 and is under extreme drought when the value is below -2.

The analysis in this report focuses on two measures: the share of land area affected by droughts and the intensity of the drought in the affected area. For each state or province in the world, the share of land affected by drought is calculated as the sum of the area of all its grid-cells with SPEI below -1, divided by its total land area. The average intensity of droughts is measured as the average SPEI value during periods when SPEI value is less than -1. The average intensify of extreme droughts is measured using SPEI<-2 as a threshold.

Analysis conducted for this report, using monthly SPEI data at grid-cell level, indicates that the Middle East and North Africa, as well as Latin America and the Caribbean, have been the most affected by droughts over the past two decades. Between 2000 and 2021, droughts have on average impacted 24 percent of the world's land area each month. However, the share of land affected by droughts was at 39 percent in the Middle East and North Africa, and 33 percent Latin America and the Caribbean. It is worth noting that the Amazon rainforest has been severely affected by droughts, with 49 percent of its land being impacted by droughts in the nine states of Brazil in which the rainforest is located (Map 4.1 panel a).

Other areas that were significantly affected by droughts include South Asia, Sub-Saharan Africa, and East Asia and the Pacific, where droughts have affected 23, 22, and 22 percent of the land, respectively. In contrast, Europe and Central Asia and North America were the least affected regions, with droughts impacting 20 and 15 percent of the land, respectively.[1]

Analysis conducted for this report shows that globally, an estimated 810 million people live in high poverty and high drought risk hotspots (Map 4.1 panel b). These hotspots are defined as states or provinces where more than 66 percent of the population lives on less than $6.85 per day and where the incidence of droughts is high (more than 24 percent of the land was affected by droughts between 2000 and 2021). About 76 percent of these hotspots are located in Sub-Saharan Africa, with smaller concentrations in the Middle East and North Africa (10 percent) and in South Asia (7 percent).[2] Additionally, 1.2 billion people, mostly in South Asia, reside in hotspots characterized by high poverty levels and medium drought incidence.[3] Lastly, 203 million individuals live in areas with medium poverty rates (33 percent to 66 percent of the population living on less than $6.85 per day) and high drought incidence.[4]

Between 2000 and 2021, droughts affected middle-income countries more (Figure 4.2). In this period, droughts affected 26 percent of the land of upper- and lower-middle-income countries each month. In low-income countries the share of land affected was 23 percent whereas in high-income countries it was 19 percent. Middle- and low-income countries also experienced more extreme droughts and more intense droughts than high-income countries.

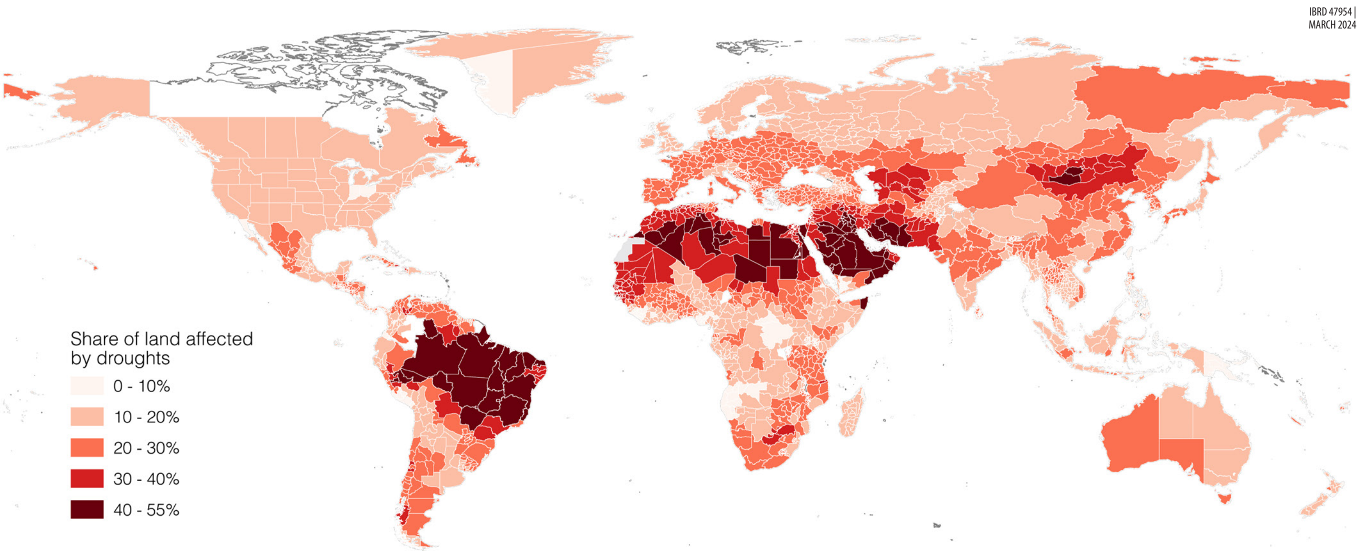
Drought assessment using models of future climate scenarios shows that increases in temperature rather than reductions in precipitation play the biggest role in increasing drought likelihood. The global land area affected by meteorological drought is projected to increase by 15 percent by 2100 and to nearly 50 percent when temperature effects are included. The most affected areas will be Central Europe and Asia, the Horn of Africa, India, North America, Amazonia, and central Australia (Spinoni et al. 2020). Poor farmers without access to irrigation will become increasingly exposed to changes in rainfall patterns and the severity of drought.

WHAT ARE THE IMPACTS?

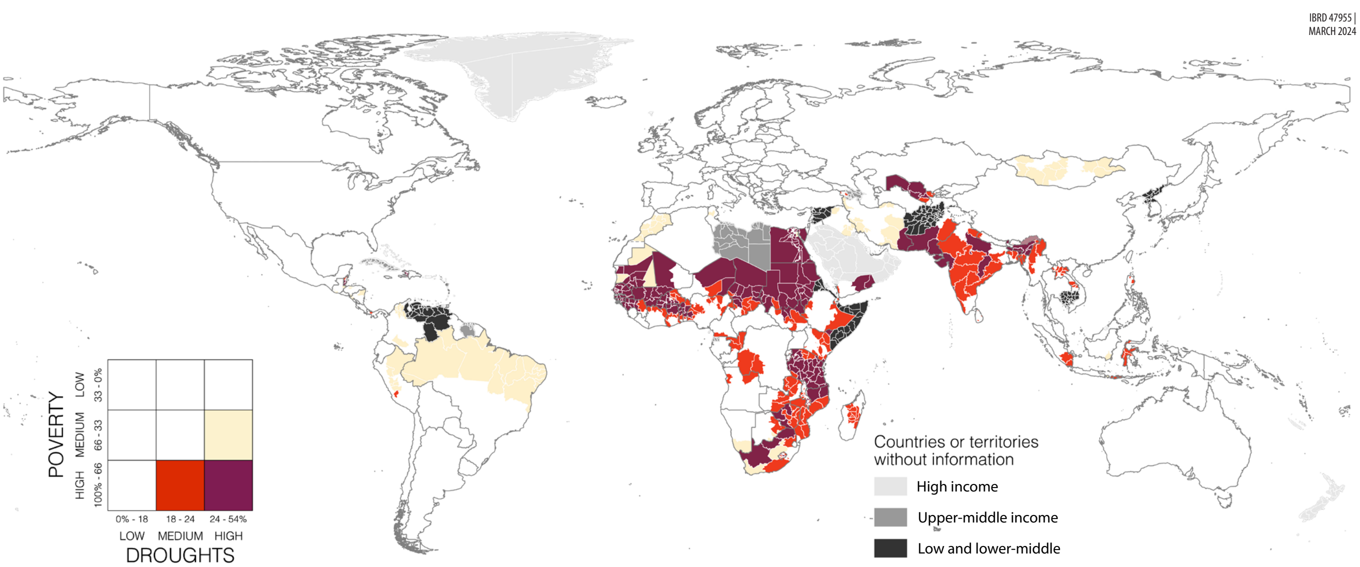
Droughts can have diverse impacts, ranging from reduced crop yields and increased food prices to drinking water shortages and conflicts over resources. As a result, droughts can negatively affect all four building blocks of prosperity. In addition, droughts can deplete productive and human capital and affect risk attitudes and technology adoption, leading to long-term consequences that go beyond the immediate impact on water availability. Civil conflict, poor governance, poverty, and disease, among other factors, increase vulnerability to drought in developing countries.

MAP 4.1 Droughts and poverty hotspots are concentrated in Sub-Saharan Africa and South Asia

a. Location of droughts



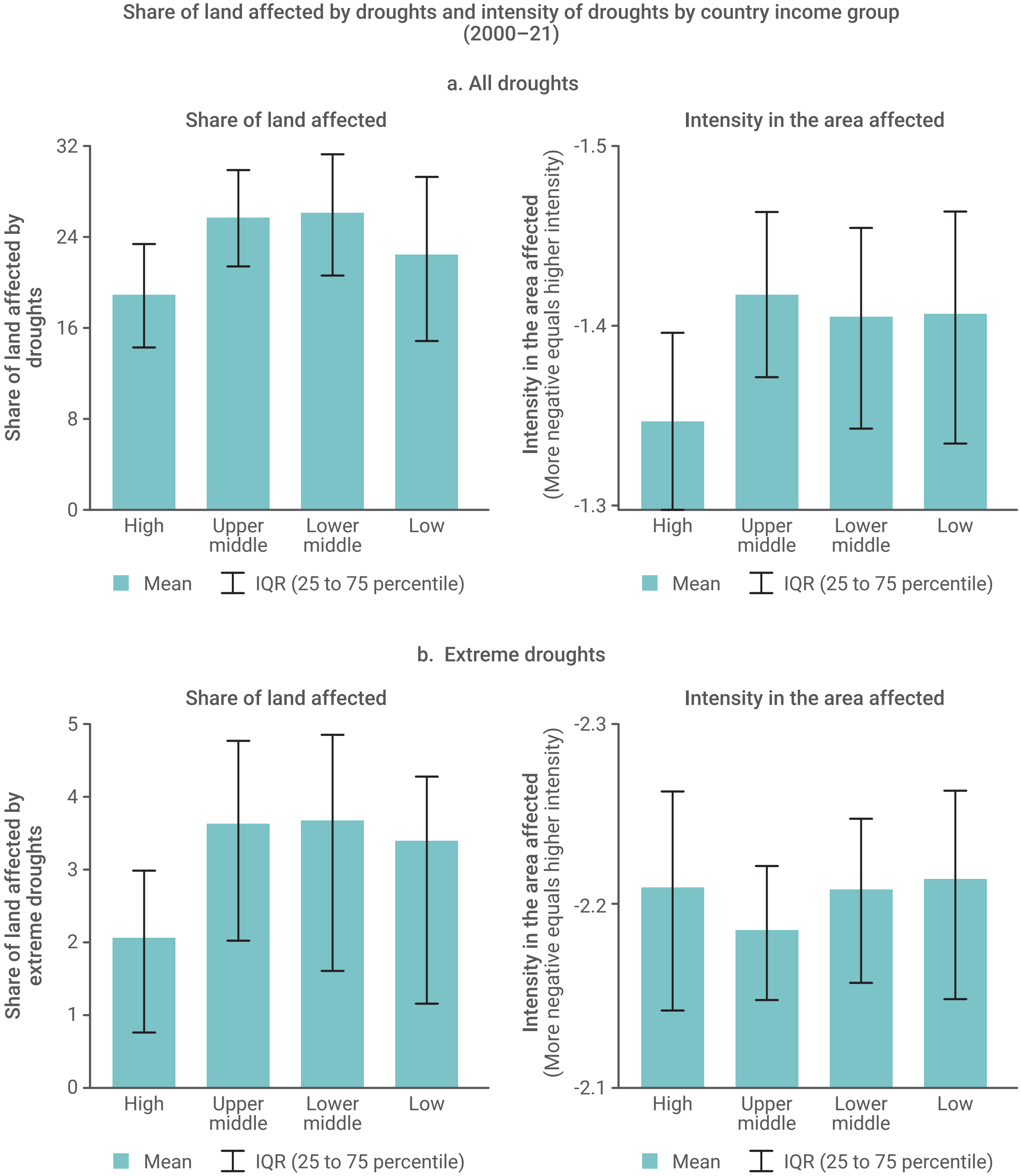
b. High vulnerability hotspots for poverty and droughts



Source: World Bank.

Note: Analysis is based on (1) poverty data at the state and province levels, obtained from The World Bank's Global Subnational Atlas of Poverty (GSAP) and the Geospatial Poverty Portal of the World Bank Group, and (2) drought data obtained using the SPEI from the Climatic Research Unit's dataset at the University of East Anglia. Panel a identifies droughts at the state or province level by depicting the average share of land affected by droughts each month between 2000 and 2021. Panel b presents hotspots for poverty and droughts. To identify hotspots, states and provinces are classified into nine categories based on a combination of three poverty categories (low, medium, high) and three incidence categories (low, medium, high) of droughts. However, panel b of the maps only displays three categories: (i) high poverty and high incidence (shown in dark red), (ii) high poverty and medium incidence (shown in red), and (iii) medium poverty and high incidence (shown in yellow). The poverty categories are based on the share of population living below the $6.85 a day poverty line (2017 PPP) in 2019, with low, medium, and high categories defined as below 33 percent, between 33 and 66 percent, and above 66 percent, respectively. The incidence categories are based on the share of land affected by droughts between 2000-01 and 2021-12, with low, medium, and high categories defined as below 18 percent (33 percent of all states and provinces), between 18 and 24 percent (33 percent), and above 24 percent (33 percent), respectively. States and provinces where both poverty and the incidence of droughts are in the high category are considered high-vulnerability hotspots for poverty and droughts.

FIGURE 4.2 Middle-income countries have been hit the hardest by droughts



Source: World Bank.
Note: Analysis is based on the SPEI (Standardized Precipitation-Evapotranspiration Index) from the University of East Anglia Climatic Research Unit's dataset. For each country income group, share of land affected is the sum of the area of all the grid-cells with SPEI below -1 divided by total area. The intensity of droughts is the mean of the SPEI of the grid-cells with SPEI below -1. The intensity of extreme droughts is the mean of the SPEI of all locations with SPEI below -2. The inter-quartile range (IQR) denotes the range of values between the bottom 25 and 75 percent of the observations.

Jobs and income

Droughts can decrease economic productivity by reducing agricultural output and tourism, disrupting shipping and energy production, and increasing energy prices. Developing countries and poor farmers are more susceptible to droughts' impacts due to (1) their higher reliance on agriculture and natural resources, (2) inadequate infrastructure and water management systems to absorb shocks, and (3) limited capacity to recover from shocks (Obsi Gemeda and Dafisa Sima 2015; de Azevedo Reis et al. 2020).

For example, Zaveri, Damania, and Engle (2023) found that low- and middle-income countries are considerably more vulnerable to rainfall deficits than higher-income countries. In low- and middle-income countries, extreme drought reduces growth by about 0.85 percentage points. By contrast, in high-income countries, extreme droughts reduce growth by a little less than half the impact felt in developing countries. Similarly, International Monetary Fund (IMF) estimates show that a single drought can lower an African country's medium-term economic growth potential by 1 percentage point, almost 60 percent more than in other emerging markets and developing economies (IMF 2021).

Droughts can have significant long-term economic implications for the world's poor. In *ex ante*, rainfall shocks can shape risk attitudes and allocation of production resources (Rosenzweig and Binswanger 1993; Rosenzweig and Wolpin 1993). In low-income settings, weather risks are uninsured or only partially insured. The presence of uninsured risks tends to heighten individuals' risk aversion (Liebenehm, Schumacher, and Strobl 2024). It lowers productivity by shifting investment away from income-maximizing to risk-reducing activities or by discouraging investment altogether (Di Falco and Chavas 2009; Amare and Shiferaw 2017). For example, farmers in Shinyanga, a semi-arid district in western Tanzania, with limited options to insure against weather risks, were found to grow lower-return but safer crops (sweet potatoes), forgoing up to 20 per cent of their income as implicit insurance premium (Dercon 1996). In Ethiopia, rainfall risks discouraged poor farmers from adopting and using fertilizer, causing inefficiencies in production choices (Dercon and Christiaensen 2011).[5]

In *ex-post*, poor farmers are more likely to rely on rainfed agriculture, therefore becoming more vulnerable to weather conditions. In addition, a common coping strategy for people experiencing extreme weather events is to sell their livestock and durable assets or borrow money for survival. Selling assets reduces their ability to generate income (Pandey, Bhandari, and Hardy 2007; Pandey and Bhandari 2009; Sherwood 2013). As these events become more frequent and severe, farmers borrowing money are less able to pay off the debt from previous events, potentially being trapped in a cycle of debt and hardship (Atiqul Haq 2022).

In summary, due to their limited assets and ability to insure against weather risks, poor households are particularly susceptible to the *ex-ante* and *ex-post* impacts of droughts. Amare et al. (2018) found that droughts disproportionally affect asset-poor and land-poor households in Nigeria. The differential impact is stark, with asset-poor households experiencing a 60 percent reduction in household consumption on average due to negative rainfall shocks, compared with a 19 percent reduction for asset-nonpoor households. Similarly, Boansi et al. (2021) found droughts particularly affect the asset poor, with a potential impact ranging from 7 percent to 46 percent of total household income.

Droughts can also worsen affordable water access for low-income households. Water providers may use expensive short-term measures such as curtailment or investing in additional water supplies to ensure reliability. However, these measures can raise water rates and make water unaffordable, especially for low-income households. For example, recent droughts in California showed that high-income households can cut back water use significantly, lowering their average water bill even with a higher water tariff. Lower-income households, however, tend to have less flexibility in their water use, and they pay higher water bills during drought periods, which reduces their water security (Rachunok and Fletcher 2023).

In addition, droughts can have a global impact through their influence on shipping and trade. For example, a severe drought at the Panama Canal has been affecting global trade since 2023. The transit of every ship through the Panama Canal's lock system uses nearly 200,000 cubic meters of fresh water supplied by artificial reservoirs (Carse 2017). The Panama Canal carries 5 percent of global maritime trade, and water restrictions reduced trade throughput by an estimated 15 million tons in 2023 (Arslanalp et al. 2023). These restrictions continue to have adverse consequences not only for consumer prices but also for employment opportunities along the supply chain.

Health and education

Droughts primarily affect health through two channels: food and nutrition, and water-related diseases. First, droughts can reduce agricultural production, which can lead to higher food prices and lower diet variety and nutrient intake (Trinh, Feeny and Posso 2021). Droughts can also affect incomes (as outlined above), limiting food intake, water use, and other essential household expenditures (Howard et al. 2020).

The 2015–18 drought in the Western Cape in South Africa, for example, resulted in a decrease in agricultural production and an increase in food prices, especially for staple foods like maize (World Bank 2022c). In the Sahel region, the 2016–20 drought harmed more than 20 million people through a sharp increase in food prices and food insecurity (World Bank 2022a). Likewise, the worst meteorological drought in the past two decades in the Horn of Africa resulted in a severe food security crisis in Somalia, Kenya, and Ethiopia, affecting more than 21 million people in the region. In Afghanistan, households responded to the 2018 drought by reducing both food and non-food consumption (Kochhar and Knippenberg 2023).

Second, droughts can increase the prevalence of water-related diseases such as diarrhea and malaria. When rainfall decreases, viruses, bacteria, and protozoa can pollute groundwater and surface water (Mosley 2015). Droughts have been shown to increase the probability of malaria epidemics in Venezuela (Bouma and Dye 1997). Poor people are also more vulnerable to malaria because they lack preventative measures like mosquito nets and insecticides, and they have less access to healthcare. People who don't have access to safely managed water are also at higher risk for drought-related infectious diseases.

The impact of droughts on health can persist long after the drought has ended. For example, Moobi and Kalaba (2018) found that households continue to pay higher prices for maize even during drought recovery periods, when prices are expected to decline because cost savings from producers were not passed onto consumers. More importantly, as discussed in Chapter 1, droughts associated with maternal malnutrition and undernourished early childhood development, can have long-lasting impacts, even across generations, on health, cognitive development, and other economic outcomes.

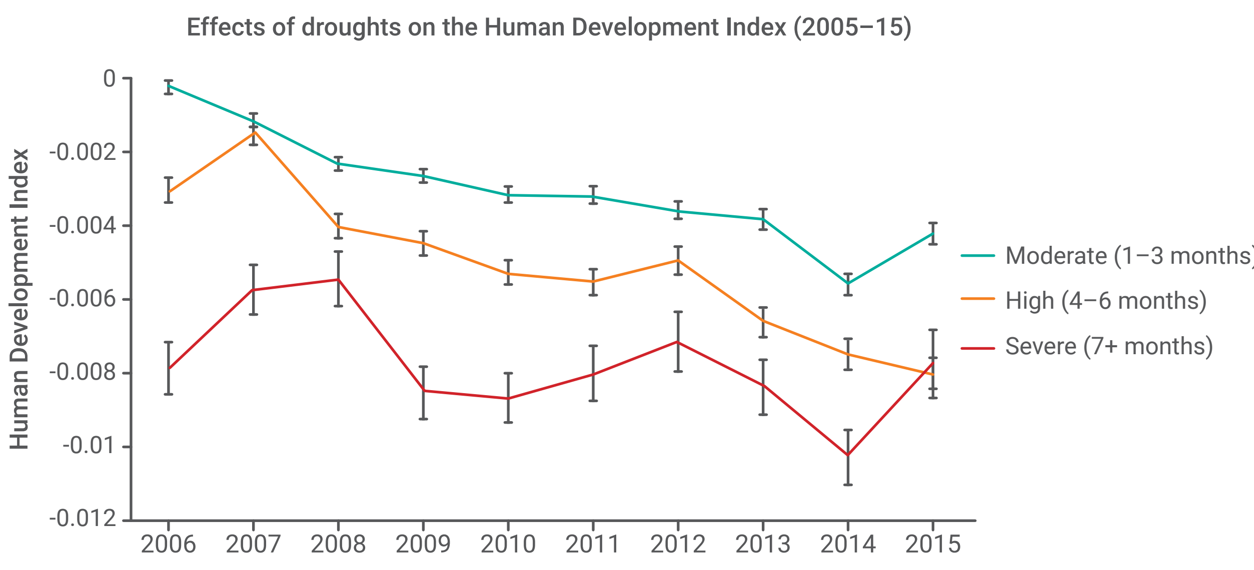
Droughts and rainfall shocks can cause disinvestment in human capital development due to the income effects of climate shocks, which particularly affect women. Sherwood (2013) shows that drought conditions can perpetuate poverty traps and exacerbate a "poverty of time and energy" among women. Maitra and Tagat (2019) reported that women's attendance in educational institutions is reduced during droughts.

Through these multiple channels, droughts can have a significant impact on human capital development. Indeed, the analysis carried out for this report has revealed a significant negative correlation between droughts and their duration and the Human Development Index (HDI) for 179 countries during the period of 2005–15 (Appendix B). A severe drought, which is defined as a drought lasting for at least seven months during a single year, is found to be associated with an average annual decline of 0.8 percent in the HDI (Figure 4.3). A high-level drought, which is defined as a drought lasting between four to six months during a single year, is associated with an average annual decline of 0.6 percent in the HDI.

Peace and social cohesion

In addition to imposing economic and human capital losses, droughts can threaten the peace and stability of a society. As discussed in Chapter 1, output and income decreases induced by droughts can lower the opportunity cost of engaging in conflicts, and increased food prices and economic stress on households may spill over into broader political instability, forcing migration from drought-stricken areas. Increased competition for water could lead to conflict as well. With expected increase in the frequency and severity of droughts, studies have projected increased rates of human conflicts

FIGURE 4.3 Droughts and their duration are negatively correlated with the Human Development Index



Source: World Bank.
Note: Analysis is based on a sample of 674,069 observations for 179 countries at state or province levels during 2005-15. A severe drought is defined as a drought lasting for at least seven months during a single year. A high-level drought is defined as a drought lasting between four to six months during a single year. Finally, a moderate drought is defined as a drought lasting between one to three months during a single year. The HDI consists of a composite index of life expectancy, education, and per capita income indicators. It is widely recognized as the main measure of human development worldwide. HDI ranges from 0 to 1, with higher values indicating higher levels of human development. The usual unit of measure is 0.01, which equals one percentage point of the index.

as a critical impact of climate change (Hsiang, Burke, and Miguel 2013; Harari and La Ferrara 2018). Regions and countries that are already grappling with conflicts and dwindling social capital are more vulnerable to potential political and civil unrest due to water scarcity (Chapter 1).

Environment

Evidence suggests that droughts and desertification have significant impacts on the environment. When the environment is affected by droughts and desertification, natural ecosystems are modified, increasing risks to ecosystems and human well-being. The environmental consequences of droughts and desertification include soil degradation, changes in vegetation cover, loss of wildlife habitats, leading to ecosystem instability, loss of biodiversity and reduced ecosystem services (Vogt et al. 2011; Xu et al. 2009). Droughts and desertification also affect water quality, fish population, and disrupts aquatic ecosystems (Palmer et al. 2008; Crausbay et al. 2017).

Droughts also increasingly affect wetlands. Reduced precipitation and increased evapotranspiration hinder water infiltration into the soil, limiting the water purification capacity of wetlands. Andean wetlands called paramos can store equally large amounts of soil organic carbon and vast quantities of water, forming wetlands crucial for the sustainability of downslope Andean ecosystems and human settlements. In countries such as Ecuador and Colombia, prolonged droughts have affected these wetlands.

FLOODS: AN INUNDATION OF INJUSTICE

Flooding is when an area that is usually dry becomes submerged in water. It is the most frequently occurring and damaging natural hazard (Jongman et al. 2018). There are several types of flooding. Flooding from overflowing rivers is known as fluvial flooding and occurs because of prolonged rainfall or melting snow in a catchment. Pluvial flooding is when rainfall pools on land that cannot absorb it due to impermeable surfaces or because urban drainage systems have become overwhelmed. Flash flooding is when intense rainfall leads to the rapid and intense flow of water. Prolonged rainfall can also cause water tables to rise, leading to groundwater flooding. In coastal areas, storm surges and high tides can lead to coastal flooding.

WHO IS AFFECTED?

Throughout history, humans have often chosen to settle in areas prone to flooding (Di Baldassarre et al. 2013) because rivers are essential sources of freshwater (Kummu et al. 2011), and floodplains offer fertile soil for agriculture (Crawford et al. 1998). Additionally, rivers and coasts serve as centers of industry and trade, offering economic opportunities to communities (Fang and Jawitz 2019). Rentschler, Salhab, and Jafino (2022) found that 1.81 billion people, or 23 percent of the global population, live in areas exposed to significant risks of fluvial, pluvial, and coastal flooding.[6] In the past three decades, there has been an increase in urbanization in areas prone to flooding (Andreadis et al. 2022; Rentschler et al. 2023). In fact, even regions that have recently experienced flooding have seen an increase in exposure. In a global study of over 900 flood events since 2000, Tellman et al. (2021) estimated that the number of individuals residing in these locations rose 58 million to 86 million between 2000 and 2015.

Flood exposure is widespread, but the poor suffer disproportionally from floods. Most of the global population exposed to significant flood risks resides in low- and middle-income countries (McDermott 2022). The majority are located in South and East Asia. China and India combined account for more than one-third of this exposure (Rentschler, Salhab, and Jafino 2022).

The regions most affected by floods are South Asia and East Asia and the Pacific (Map 4.2, panel a). Globally, 23 percent of the population is at high risk of floods, with South Asia being the most vulnerable, where 31 percent of the population is at high risk of floods, followed by East Asia and the Pacific with 28 percent. The Middle East and North Africa are the next most impacted region, with 20 percent of the population at high risk of floods. The Arab Republic of Egypt (41 percent) and Iraq (36 percent) are particularly susceptible. The regions of Latin America and the Caribbean, Europe and Central Asia, and Sub-Saharan Africa follow closely behind, with 16 percent, 16 percent, and 15 percent of their respective populations at high risk of floods. North America is the least affected region, with only 12 percent of the population at high risk of floods.[7]

Analysis conducted for this report shows that globally, an estimated 1.6 billion individuals reside in high poverty and high-risk flood hotspots (Map 4.2, panel b). These hotspots are defined as states or provinces where flooding risks are high (Box 4.2) and where more than 66 percent of the population is living on less than $6.85 per day). Most of these hotspots are located in South Asia, Sub-Saharan Africa, and East Asia and the Pacific.[8] Another 1.2 billion people live in hotspots of high poverty and medium risk of floods.[9] Finally, 317 million live in areas of medium poverty (where 33 percent to 66 percent of the population are living on less than $6.85 a day) and are at high risk of floods.[10]

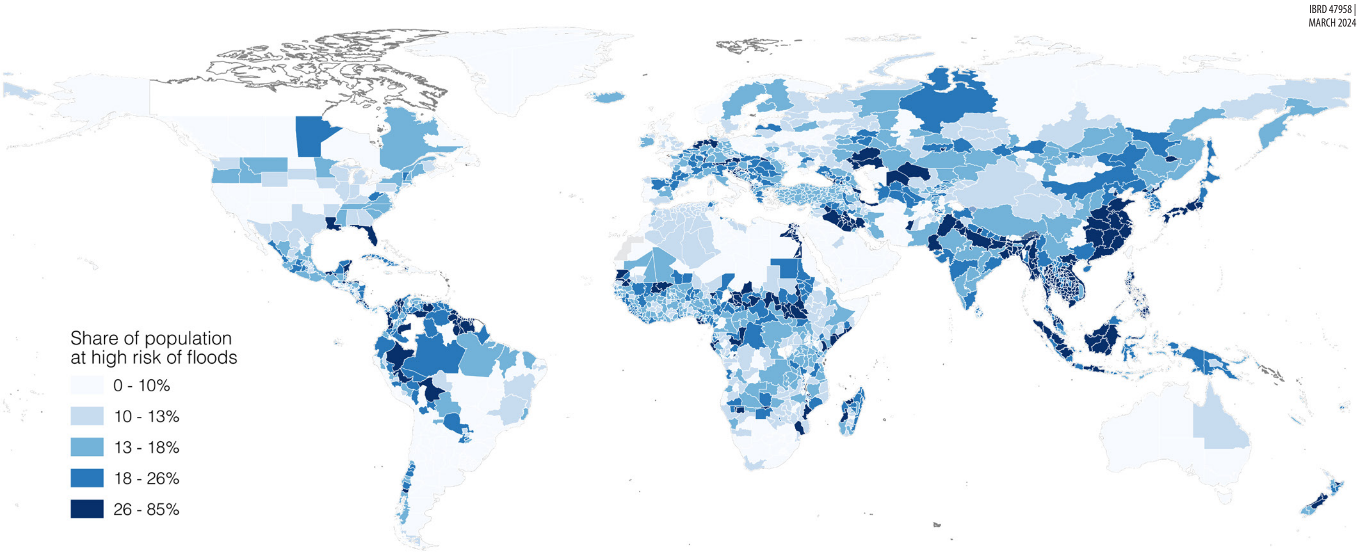
BOX 4.2 How is flood risk measured?

To explore the correlation between poverty and exposure to flood risks, this report assesses flood risks at the subnational level by examining the share of the population at significant risk of flooding. This is done by using gridded flood exposure headcount data developed by Rentschler, Salhab, and Jafino (2022). Relying on flood data from Fathom-Global 2.0, Rentschler, Salhab, and Jafino (2022) estimate population exposure to flood risk with a 3 arc second resolution (equivalent to about 90 x 90 meters at the equator) for 188 countries. Individuals are classified as exposed to high flood risks if they face inundation depths greater than 0.15 meters during a 1-in-100 year flood event. Flood risk at subnational level is categorized as (1) low—states or provinces where below 12 percent of population are at high risk of floods, (2) medium—states or provinces where between 12 and 19 percent of population is at high risk of floods, and (3) high—states of provinces where above 19 percent of population is at high risk of floods. Each category accounts for roughly one third of the world sample.

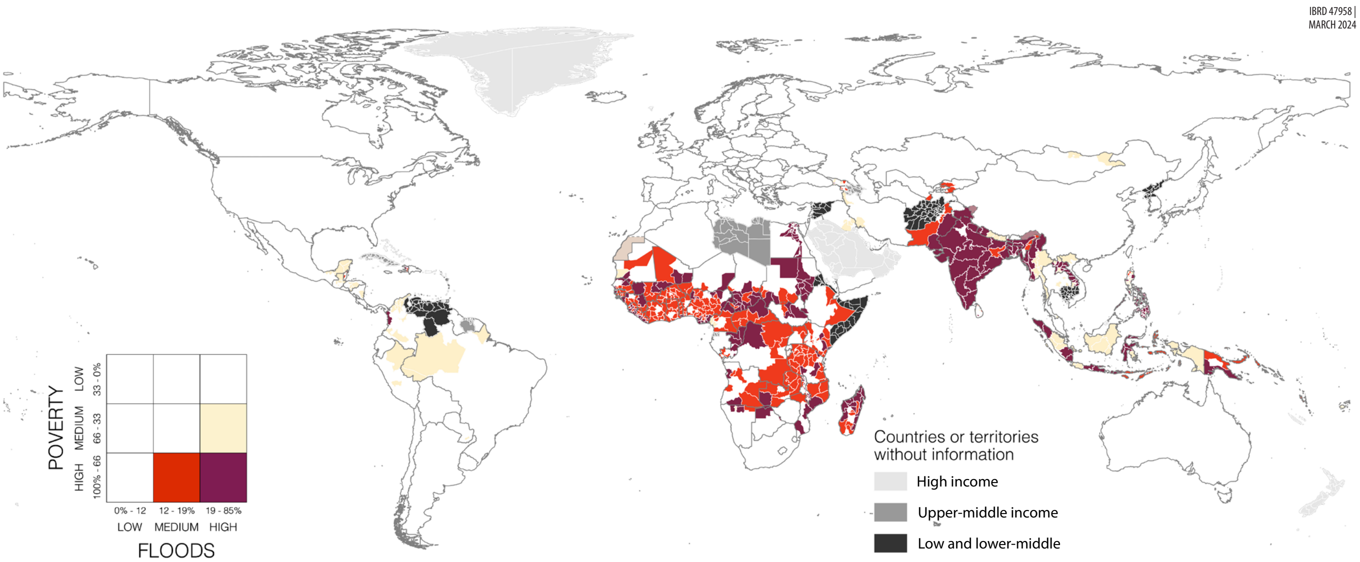
To measure duration of floods at country level, this report uses information from the Dartmouth Flood Observatory (DFO). The DFO catalogues floods that occur every one or two decades or those that, according to the DFO, cause fatalities or significant damage to structures or agriculture. This report analyzes the duration of all registered floods that have taken place between 2000 and 2021. Incomplete DFO records in time and spatial coverage could add uncertainty in the analysis findings. However, this is still one of the best flood observation datasets that are currently available for this form of global analysis.

MAP 4.2 Vulnerability hotspots for poverty and floods are concentrated in Sub-Saharan Africa, South Asia, and East Asia and Pacific Region

a. Location of floods



b. High-vulnerability hotspots of floods and poverty



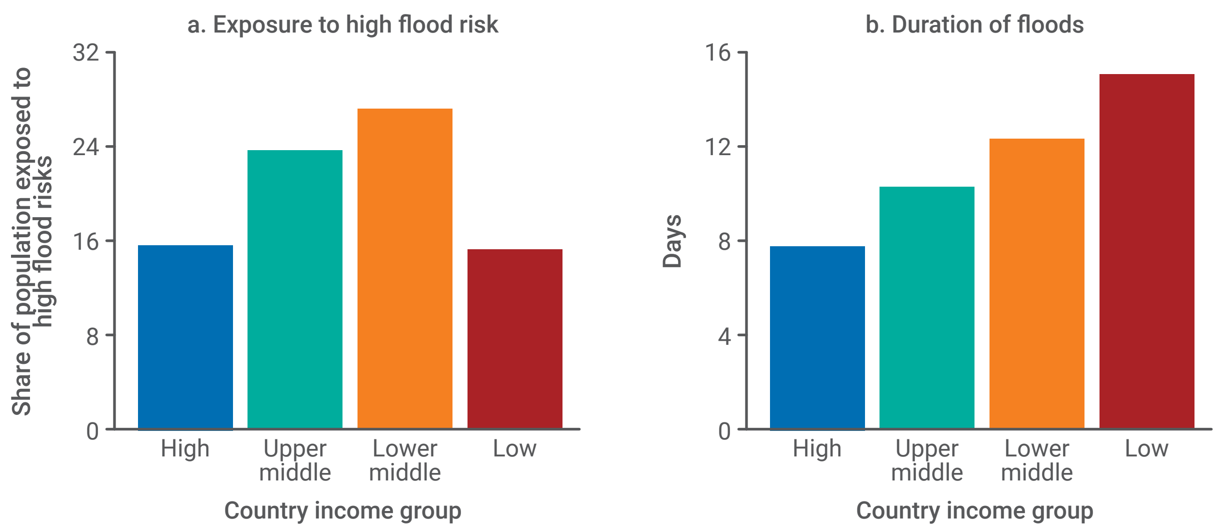
Source: World Bank.
Note: Analysis is based on state- and province-level data for (1) poverty from the World Bank Group's Global Subnational Atlas of Poverty (GSAP) and Geospatial Poverty Portal and (2) gridded exposure headcount estimates by Rentschler, Salhab, and Jafino (2022). Panel a identifies floods at the state or province level by depicting the share of population at high risk of floods. This is the population exposed to an inundation depth of 15 cm during a flood event with a 100-year return period. Panel b presents hotspots for poverty and floods. To identify hotspots, states and provinces are classified into nine categories based on a combination of three poverty categories (low, medium, high; refer to Map 4.1) and three risk categories (low, medium, high; refer to box B.4.2.). However, panel b of the maps only displays three categories: (i) high poverty and high risk (shown in dark red), (ii) high poverty and medium risk (shown in red), and (iii) medium poverty (shown in yellow). States and provinces where both poverty and the risk of floods are in the high category are considered high-vulnerability hotspots for poverty and floods.

Middle-income countries are more exposed to high flood risks, while low-income countries experience longer-lasting floods (Figure 4.4). In high-income countries, about 16 percent of the population is at high risk of floods. The proportion is significantly higher for upper-middle-income (24 percent) and lower-middle-income (27 percent) countries. For low-income countries, the proportion is at 15 percent, but these countries experienced floods that lasted for a longer duration. Globally, between 2000 and 2021, large floods on average lasted 12 days. However, in high-income countries, large floods lasted for an average 8 days, while in low-income countries, they lasted for an average 15 days. This difference in duration could be related to several factors. It may be that there are relatively more big rivers, and hence longer floods, in low-income countries. It may also be related to better infrastructure and flood management resulting in shorter flood durations. While the correlation is evident from the analyses, the specific mechanisms require further study.

Flood risk is positively correlated with poverty rate at state and province level (Figure 4.5). The average poverty rate (living on less than $6.85 a day) is 36 percent in states and provinces at low risk of flooding. It is 52 and 50 percent in states and provinces at medium and high risk of flooding, respectively. However, within states, areas with higher poverty are not necessarily facing higher risks of floods because flood risk tends to be higher in urban areas.[11]

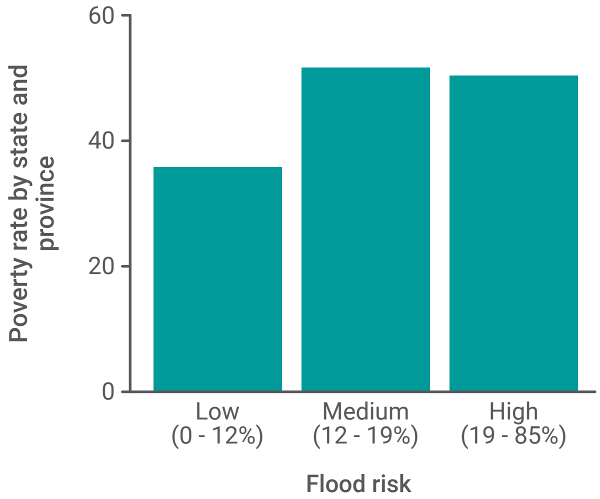
In urban areas, the poor are disproportionally at risk from flooding. Despite the perceived riskiness of flood-prone areas, socioeconomic factors often force the poor to settle in these areas (Hallegatte 2012). For instance, low-cost housing in flood-risk areas is more affordable for the poor than other options (Zhang 2016). Consequently, poor people are less willing and less able to pay for safety from flooding (Jongman et al. 2018; Winsemius et al. 2018). In most countries where data exist, poor urban households are more exposed to floods than the average urban population (Hallegatte 2016). For example, in Viet Nam, informal slum settlements in Ho Chi Minh City are more exposed to flooding than in other urban areas (Bangalore, Smith, and Veldkamp 2019). In Bago City in Myanmar, poor households are more likely to reside in areas subjected to more severe flooding (Kawasaki, Kawamura, and Zin 2020).

FIGURE 4.4 Middle-income countries are more exposed to high flood risks while low-income countries experienced longer duration of floods



Source: World Bank.
Note: Analysis is based on (1) gridded exposure headcount estimates by Rentschler, Salhab, and Jafino (2022) and (2) records of duration of large floods taking place between 2000 and 2021 from the Dartmouth Flood Observatory (DFO). Exposure to high flood risk is the share of the population exposed to an inundation depth of 0.15 meters during a 1-in-100 year flood event.

FIGURE 4.5 Flood risk is positively correlated with poverty rate at state and province level



Source: World Bank.
Note: Analysis is based on gridded exposure headcount estimates by Rentschler, Salhab, and Jafino (2022). States and provinces are grouped in three categories according to share of the population exposed to an inundation depth of 0.15 meters during a 1-in-100 year flood event. The three categories are: (1) low—below 12 percent, (2) medium—between 12 and 19 percent, and (3) high—above 19 percent. Each category accounts for roughly one third of the world sample. Poverty rate is the share of the population living under $6.85 a day (2017 PPP) in 2019.

Climate projections using the latest Coupled Model Intercomparison Project Phase 6 (CMIP6) suggests that river flood exposure due to global warming is projected to increase in Asia, South America, and Sub-Saharan Africa, whereas flood exposure is projected to decrease in northern and eastern Europe.[12] Projected increases in riverine flooding exposure are particularly significant in Africa and Asia. With 3 degrees Celsius warming, by the century's end, Africa is expected to see a 1.7-fold, and Asia a 1.5-fold, higher flood risk than the average of 1971–2000 (Hirabayashi et al. 2021). Coastal flooding is also projected to increase in extent and severity due to future sea level rise (Kulp and Strauss 2019) and storm surges, with future hotspots expected to be concentrated in Asia and north-western Europe (Kirezci et al. 2020).

WHAT ARE THE IMPACTS?

Floods and droughts, while opposite in terms of rainfall shocks, can have similar impacts on livelihoods and well-being. Excess rain can lead to crop damage, livestock losses, lower food supplies, decreased agricultural income, and increased waterborne disease. However, unlike droughts which tend to have a slow onset impact, floods can cause rapid damage to infrastructure and property, causing injuries, displacement, and loss of shelter.

The cost of flooding globally since 1980 has already exceeded $1 trillion, an amount expected to double by 2030 (Kuzma and Luo 2020). In the last five years alone, losses from flooding worldwide amounted to $300 billion, of which only roughly $45 billion was insured (Munich RE 2020). Recent events have shown how deadly and damaging floods can be: Flooding in Germany led to the deaths of more than 180 people in the summer of 2021 (Lehmkul et al. 2022), and floods in Pakistan displaced more than 30 million people and led to economic losses greater than $30 billion in the following summer (Nanditha et al. 2023). Subsequent attribution studies have found that climate change made flooding in Germany more likely (Tradowsky et al. 2023) and flooding in Pakistan more intense (Otto et al. 2023).

Flood impacts, much like drought impacts, vary greatly across different socioeconomic groups. The poorest and most marginalized populations are the most vulnerable to floods. They often lack flood protection measures, and have less capacity to smooth consumption in the aftermath of a flood and as a result have to engage in suboptimal coping strategies. Similar to the impact of droughts, the cumulative and interconnected impacts of floods on the income, education, and health of the impoverished people can perpetuate a cycle of poverty.

Jobs and income

Floods can significantly impact economic infrastructure and systems, reducing employment opportunities and real wages, disrupting markets, and increasing commodity prices for both rural and urban communities. Consequently, affected households can face reduced incomes and lower purchasing power, often resulting in reduced food consumption and expenditure on basic durables.

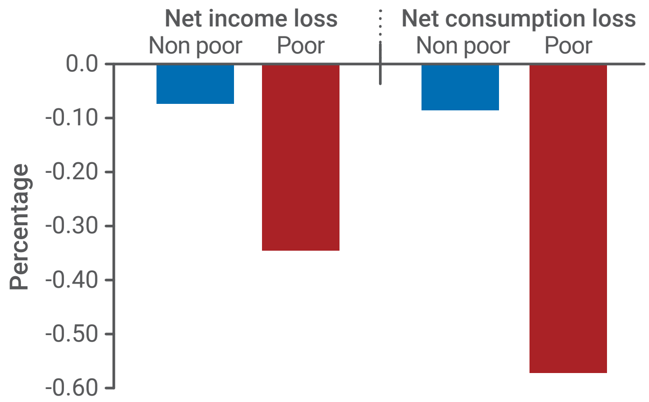
Based on the analysis of the welfare impacts of floods in 24 countries in Sub-Saharan Africa, Azzarri and Signorelli (2020) found that flood shocks—characterized by annual rainfall exceeding one standard deviation from the 50-year average—result in a substantial decrease in total and food per-capita consumption both by around 35 percent and an increase in extreme poverty by 17 percentage points. Smallholder farmers emerge as particularly susceptible to the weather. For example, Baez, Fuchs, and Rodríguez-Castelán (2017) revealed that the most intense tropical storm in Guatemala played a significant role in pushing nearly 80,000 additional families into poverty, mostly in urban areas.

Poor households suffer disproportionally from floods. The losses from water shocks are often communicated in loss or damage to assets. The equivalent loss of assets for a low-income household compared with a high-income household would have a greater relative impact on the low-income household because the assets represent a greater proportion of the low-income household's wealth. In Mumbai, surveys conducted on households following an exceptional flood in 2005 found that households below the poverty line experienced losses equivalent to six times their monthly income, while higher-middle-income groups experienced losses only twice their monthly income (Patankar and Patwardhan 2016).

Similarly, empirical evidence from Malawi spanning 2016 to 2019 illustrates that households experiencing floods once every four years witness a minimum 17 percent reduction in their agricultural income, and floods are estimated to increase the poverty rate by 30 percentage points for the bottom 40 percent, compared with 14 percentage points among the overall affected population (World Bank 2022b). The distributional analysis of flood impacts in Colombia revealed a similar pattern (Figure 4.6).

Beyond immediate economic loss, poor households face higher uninsured flood risks, which makes them more risk-averse and more likely to forgo high-risk and high-return growth opportunities. In low-income countries, disaster insurance is often unavailable due to high transaction costs and weak institutions (Hallegatte et al. 2020). Even when it is available, take-up remains low particularly among the poor because of affordability issues (Grislain-Letrémy 2018; Pierro and Desai 2008).

FIGURE 4.6 Distributional analysis of flood impacts in Colombia



Source: World Bank (2020).

Health and education

Flooding has more direct tangible impacts on health than droughts (Du et al. 2010; Stanke et al. 2013). These impacts can include drowning, injuries, hypothermia, and disruption to access to health facilities. Like droughts, floods increase the risk of vector-borne diseases, which can occur when flood water combines with sewage (Miller and Hutchins 2017). Floods and heavy rain spread pathogens into water sources, causing spikes of diseases including cholera. Rivers and floodplains have been shown to be critical transmission foci for malaria in Africa (Smith et al. 2020). The incidence of floods in Asia and Africa has increased the occurrence of diarrhea and respiratory infections in children living in informal settlements and slums (IPCC 2022). The barriers posed by Zambezi floodwaters hinder women's ability to reach healthcare facilities promptly (Mroz et al. 2023).

Floods can also affect child nutrition, as poor households with limited assets respond to income loss and higher food prices by reducing the quality and quantity of nutrition provided to children (Hallegatte, 2016). Studies in low- and middle-income countries have found that floods can lead to undernutrition in children under-five years of age (Agabiirwe et al. 2022).

In Bangladesh, for example, children living in villages severely exposed to floods experienced a two-fold increase in stunting (Agabiirwe et al. 2022). The trauma experienced by those affected by floods and droughts can also lead to (or worsen) mental health conditions, particularly for children (Dean and Stain 2007; Cheema et al. 2023).

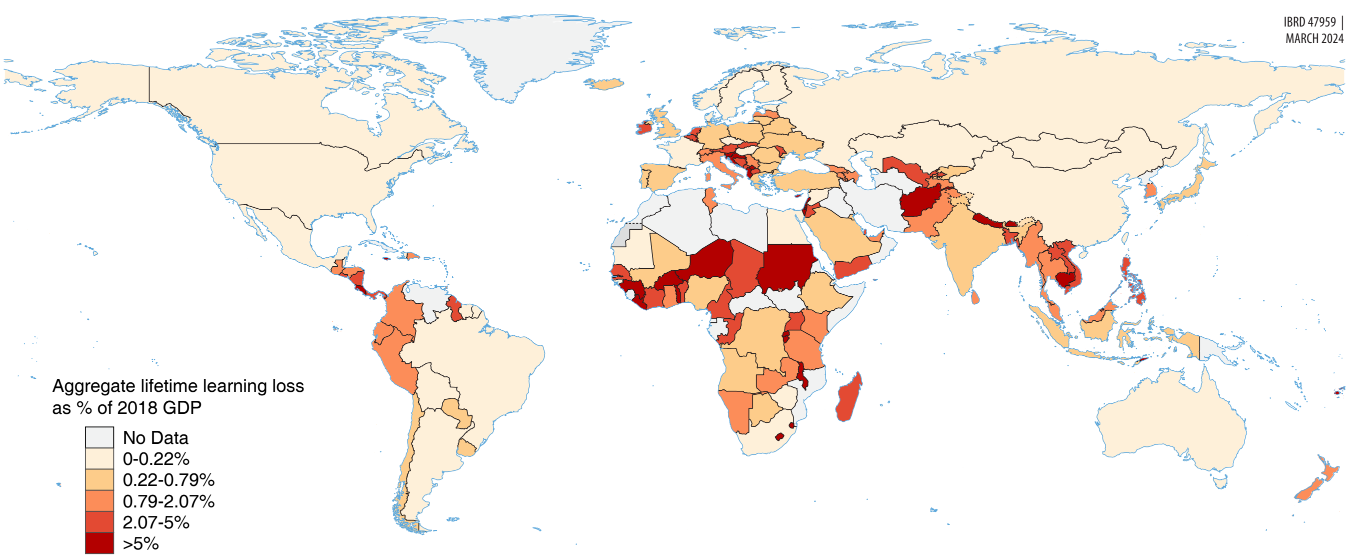
Floods can also have a negative impact on education, particularly for the poor, as households attempt to mitigate the income effects of floods through increased labor supply by children. Baez, Fuchs, and Rodríguez-Castelán (2017) found that child labor increased by 10.8 percent from the pre-shock level in the aftermath of a major tropical storm in Guatemala, with the largest increase observed in flood-affected rural villages. In Pakistan, analysis of household surveys conducted before and after the 2010 floods showed that the floods led to a sharp rise in school dropout rates, with a measurable impact on literacy rates and education levels (Khan and Karrar 2023).

In addition, floods can affect school attendance by disrupting physical access to school facilities. Following the approach of Azevedo et al. (2021), analysis conducted for this report estimates the impact of floods on schooling days and lifetime income (Appendix B). Based on grid cell level precipitation and population data, the analysis reveals that, globally, from 2000 to 2022, more than 139 million school-age children in 147 countries were affected by extreme wet shocks lasting an average of 1.83 months per year.[13]

Assuming children stayed out of school during extreme rainfall shocks, learning-adjusted years of schooling (see Filmer et al. 2020) fell by an average of 0.12 percent for school-age children. This decline in education could lead to a decline in lifetime earnings of $4,361 PPP per person on average, resulting in an aggregate income loss of more than $565 billion at the global level. The extent of the impact varies across countries, with low-income countries being particularly affected. Map 4.3 provides an illustration of this variation. It aggregates the lifetime earning loss at the country level and compares it to the GDP of a single year. The median value of lifetime earning loss due to floods during the 2000–22 period is equivalent to 1.5 percent of a single year's GDP. However, for a handful of countries in Sub-Saharan Africa and South Asia, the combined loss can surpass 20 percent of a single year's GDP.

The economic impact of rainfall shocks presented in Map 4.3 represents only lower-bound estimates. Considering the cumulative effect of extreme rainfall events, particularly given their increasing frequency and intensity due to climate change, the long-term economic impact of floods is likely to be much larger.

MAP 4.3 Aggregate lifetime earning loss due to floods is disproportionately higher in low-income countries



Source: World Bank.
Note: Analysis is based on the Standardized Precipitation Evapotranspiration Index (SPEI), harmonized learning outcomes data from Angrist et al. (2021), population data from CIESIN (2018), and Gridded Population of the World from the NASA Socioeconomic Data and Applications Center. The analysis compares lifetime earnings with and without exposure to flood shocks during the period 2000–22. The methodology accounts for the direct impact of flood shocks on schooling days and is associated with learning loss. Flood shocks are defined as an area with an SPEI greater than 2, and the gridded population is used to identify the flood-exposed school-age population.

Peace and social cohesion

Although the literature has mostly focused on the effects of droughts and water scarcity on conflicts, floods can be equally disruptive to social stability. Floods can quickly destroy lives and property, leading to social discontent, particularly in developing countries, where roads are of poor quality and extreme rain can destroy infrastructure, limiting the state's capacity to respond to disturbances around the country (Hendrix and Salehyan 2012).

Hendrix and Salehyan (2012) reveal a significant relationship between deviations from normal rainfall patterns and social conflicts in 47 African countries during the 1990–2009 period. The study revealed that both extremely dry and wet conditions are positively associated with various types of social unrest. Notably, it also showed that armed conflicts are more likely in years of abundant rainfall.

Environment

It is important to note that floods play a crucial role in creating and maintaining river and floodplain habitats. Predictable and less extreme floods create conditions for species and habitats to exist and adapt better to the environment under stable ecosystems. For instance, in the Amazon River, many fish species that local communities depend on are forest-dwelling fish that feed on leaves, fruits, seeds, and insects that fall into the river during the annual rainy season. Trees of these seasonally flooded forests have developed fruits and seeds that mature during the flooding season.

However, extreme floods can disrupt this balance, affecting fish populations and communities that depend on them. Extreme floods can have a significant impact on the environment also by causing degradation of water quality, and destruction of habitats (Aldardasawi and Eren 2021; Dube and Nhamo 2018; Qian, Wang, and Li 2022). As floods become more frequent and extreme due to climate change, the negative impacts of floods on the environment are likely to increase. It is essential to take an integrated approach to flood management to balance the needs of flood protection with the importance of maintaining healthy river ecosystems.

CONCLUDING REMARKS

Droughts and floods disproportionately affect the world's poorest populations. The compounding effect of natural hazards and poverty is further amplified when poor water supply, sanitation and lack of wastewater management exacerbate the impacts of droughts and floods, making it more difficult for poor communities to escape poverty. Prioritizing resilience and adaptation strategies in vulnerable communities around the globe is essential to achieve shared prosperity. A concerted effort is required to address interrelated hazards and incorporate disaster risk management into development planning, particularly in regions where poverty and hydro-climatic risks are highly concentrated. The next chapter includes policy recommendations aimed at improving climate resilience in order to protect the vulnerable population.

NOTES

1 By region, the countries most affected by droughts are Mongolia, French Polynesia, North Korea (DPRK), and China (East Asia and the Pacific); Turkmenistan and Uzbekistan (Europe and Central Asia); Brazil, Haiti, Venezuela, and Trinidad and Tobago (Latin America and the Caribbean); Qatar, Kuwait, United Arab Emirates, Oman, and Saudi Arabia (Middle East and North Africa); Unites States (North America); Pakistan and Afghanistan (South Asia); and Guinea-Bissau, the Gambia, Mauritius, Senegal, and Mauritania (Sub-Saharan Africa).

2 There are 191 hotspots. Tanzania, Sudan, and Senegal contain 51 of these hotspots, which affect 107 million people. India has nine hotspots (389 million) whereas Bangladesh (31 million) and Pakistan (62 million) have two each. Egypt has sixteen hotspots (81 million people). Uzbekistan has five hotspots (11 million). Haiti has six (10 million). Countries in East and the Pacific lack this type of hotspots.

3 The majority of people living in these hotspots are concentrated in just three countries in Southeast Asia – India (625 million), Pakistan (139 million), and Bangladesh (115 million).

4 The largest concentration of people living in these hotspots can be found in America and the Caribbean, with a total of 96 million people, followed by the Middle East and North Africa with 65 million individuals.

5 As a costly input, when droughts occur, returns tend to be low given the sunk cost of fertilizer, making it a high-risk and high-return activity compared to not using fertilizer.

6 Floods with depths greater than 0.15 meters and occurring with a probability of once in a hundred years.

7 By region, the countries most at high risk of floods are Viet Nam (47 percent), Myanmar (42 percent), Lao PDR (39 percent), Cambodia (38 percent) and Thailand (34 percent) in East Asia and the Pacific; The Netherlands (59 percent) in Europe and Central Asia; Guyana (38 percent) and Suriname (38 percent) in Latin America and the Caribbean; Egypt, Arab Rep. (41 percent) and Iraq (36 percent) in Middle East and North Africa; United States (12 percent) in North America; Bangladesh (58 percent), Pakistan (32 percent), Nepal (29 percent), and India (28 percent) in South Asia; South Sudan (32 percent), Republic of Congo (29 percent), Chad (27 percent), and Liberia (24 percent) in Sub-Saharan Africa.

8 There are some 283 hotspots. They are widespread in Sub-Saharan Africa, particularly in Madagascar (in which 18 million people live in hotspots), Malawi (7 million), Sudan (33 million), Liberia (3 million), Nigeria (52 million), and Chad (9 million). India has fourteen hotspots in which 742 million people live. Bangladesh has seven hotspots (171 million) and Pakistan has two (192 million). Indonesia has eleven hotspots in which 128 million people live. The Philippines has fifty (50 million), Lao PDR has thirteen (5 million), and Myanmar has six (21 million). Egypt has seventeen hotspots in which 86 million people live.

9 There are some 260 hotspots. By region, the countries with more people in these hotspots are: Indonesia (8 million), Papua New Guinea (4 million) in East Asia and the Pacific; Uzbekistan (11 million) in Europe and Central Asia; Haiti (6 million) in Latin America and the Caribbean; Yemen (2 million) in the Middle East and North Africa; India (665 million) and Pakistan (44 million) in South Asia; Nigeria (114 million), Democratic Republic of Congo (50 million) and Tanzania (43 million) in Sub-Saharan Africa.

10 The majority of people in these hotspots are in East Asia and the Pacific (216 million or 68 percent) and in Latin America and the Caribbean (38 million or 12 percent).

11 Historically, cities developed close to rivers and coasts (Andreadis et al. 2022). Between 1985 and 2015, across the world urban settlements grew by 85 percent but those exposed to a highest flood hazard grew by 122 percent (Rentschler et al. 2023). In contrast with rural areas, impervious surfaces (roads, buildings) cover most of the soil in urban areas. Impervious surfaces exacerbate floods because they cause rain to accumulate and increase the flow rate of the accumulated rain, leading to faster flowing floods (Sohn et al. 2020).

12 Extreme precipitation is expected to increase with future warming in most regions globally (Seneviratne et al. 2021). One driver of global changes in extreme precipitation is that air's moisture-carrying capacity increases with every degree of warming (Adam 2023).

13 An extreme wet shock is defined as SPEI that is at least two standard deviations above normal levels. This analysis uses grid-cell-level SPEI data to capture the time variation of water shocks. This is often missing in grid-cell-level flood datasets (e.g., those produced by Rentschler et al. 2022). Many other studies have also utilized SPEI, specifically the +2 threshold, to identify extreme wet conditions and to capture flood incidences, such as Ayugi et al. (2020), Azzarri and Signorelli (2020), Cooper et al. (2019), Ojara et al. (2021), Polong et al. (2019), and Sarkar (2022).

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Policy Recommendations

CHAPTER 5

“The water problems of our world need not be only a cause of tension, or sources of inequalities; they can also be a catalyst for cooperation.”

Kofi Annan

5 CHAPTER

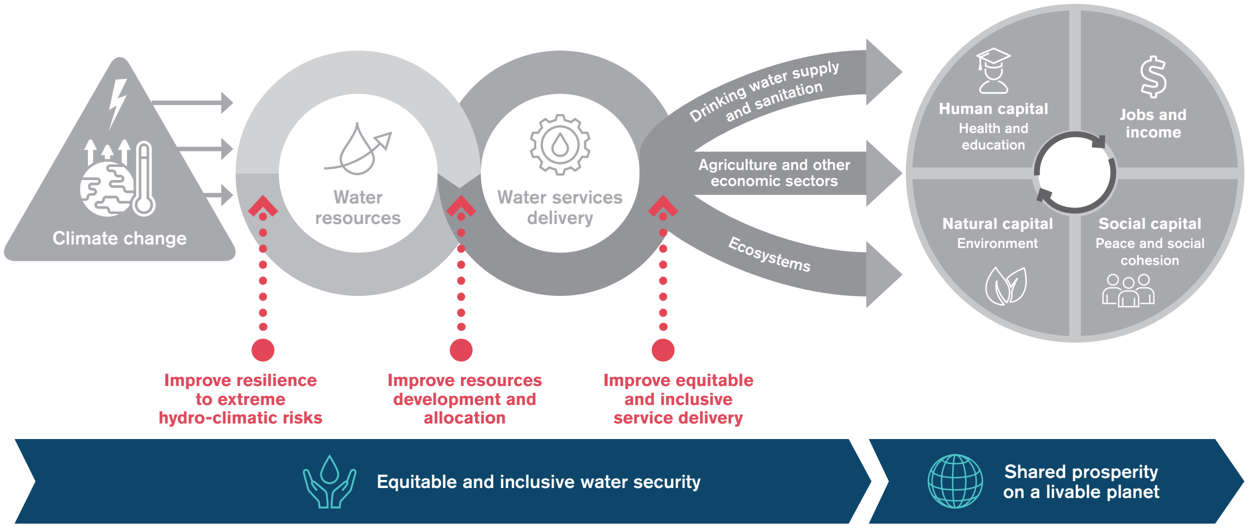
KEY MESSAGES AND FINDINGS

- Enhancing resilience to extreme hydro-climatic risks for the poorest requires
    - o Setting up robust and inclusive early warning systems
    - o Establishing insurance programs for weather risks and mitigating exposure to hydro-climatic risks through regulations and financial support
    - o Scaling up social protection schemes to assist vulnerable communities affected by floods and droughts
- Improving water resources development, management, and allocation requires
    - o Scaling up nature-based solutions through innovative financing schemes and evidence-based approaches
    - o Enabling coordination and cooperation for water allocation through information sharing and financial incentives
    - o Adopting water accounting to inform water allocation decisions
- Improving equitable and inclusive service delivery requires
    - o Scaling up financing through institutional and tariff reforms
    - o Establishing participatory water governance to ensure transparency and accountability
    - o Creating an enabling regulatory and policy environment to promote innovation
    - o Improving coordination across institutions responsible for water, health, education, and urban planning

The evidence presented in this report underscores the critical role of equitable and inclusive water security in achieving shared prosperity on a liveable planet. It also shows that water insecurity—lack of access to safely managed water and sanitation, lack of irrigation, and lack of resilience to climate-related water shocks—disproportionately affects the poor and marginalized population, contributing to widening inequalities, fragility, and conflicts.

Equitable and inclusive water security can be achieved by working simultaneously on three inter-related policy objectives: (1) improve resilience to climate-related water risks (for example, floods and droughts), (2) improve water resource management and allocation by enhancing cross-sector coordination and transboundary cooperation, and (3) improve water services delivery to promote more equitable and inclusive access to key water services, including irrigation and water supply and sanitation.

FIGURE 5.1 Three policy objectives to improve equitable and inclusive water security



Source: World Bank.
Note: Water security is defined as the availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems, and production, coupled with an acceptable level of water-related risks to people, environments and economies (Grey and Sadoff 2007). Water services include irrigation, water supply, and sanitation.

Achieving these three policy objectives towards equitable and inclusive water security requires a comprehensive package of interventions. The policy mix will need to address the dual challenge of increasing access to water resources and water services and improving resilience to extreme hydro-climatic risks and benefiting the poor and vulnerable. The specific policy interventions required may be different in different contexts. This chapter outlines a set of recommendations that policy makers can consider for achieving the above-mentioned policy objectives (Figure 5.1). These recommendations primarily emphasize the need to enhance governance, information systems, and institutions along with pro-poor investment planning and development (Table 5.1).

Addressing water access inequalities and reducing the impact of hydro-climatic extremes are critical to the World Bank's efforts to promote sustainable development and growth, reduce poverty, build resilience, and address fragility. "Fast Track Water Security and Climate Adaptation" is a recent World Bank initiative with a vision of improving global water security. Through this initiative, new support is being provided to strengthen water security and promote the reforms needed in the water sector. The initiative is designed to help policy makers develop solutions that are tailored to a country's prevailing policy, institutional, and regulatory arrangements (Box 5.1).

IMPROVING RESILIENCE TO EXTREME HYDRO-CLIMATIC RISKS

As highlighted in Chapter 4, water shocks disproportionally affect society's most vulnerable members. These events can have lasting consequences on their health, education, jobs, and income, potentially pushing them into a poverty trap. Building resilience in these communities is crucial for their economic progress. Enhancing their ability to withstand and recover from floods and droughts promotes shared prosperity.

TABLE 5.1 Key policy actions for achieving equitable and inclusive water security

Challenges	Population growth, urbanization, climate change, unequal access to water services			
High-level goal	Equitable and inclusive water security for shared prosperity on a livable planet			
Policy objectives	Improve resilience to extreme hydro-climatic risks	Improve water resources development and allocation	Improve equitable and inclusive service delivery	
			Safely managed water supply and sanitation	Sustainable agricultural water management
Policy actions	• Set up robust and inclusive early warning systems. • Develop insurance programs for extreme hydro-climatic events and risk exposure. • Develop an inclusive strategy to mitigate flood risks • Scale up social protection schemes to assist vulnerable communities impacted by floods, droughts, or both.	• Integrate nature-based solutions into water resources management programs. • Provide incentives and facilitate information sharing to enable cooperation and coordination in water allocation. • Adopt water accounting to inform water allocation decisions.	• Scaling up financing through institutional and tariff reforms. • Reform water information systems to target pro-poor investments and monitor equitable and inclusive progress. • Promote innovation in technology, finance, contractual arrangements and program design. • Improve transparency and accountability of water institutions. • Enhance collaboration among institutions.	• Broaden the intervention from irrigation expansion to agricultural water management. • Promote decentralized water management for agriculture. • Expand innovation for small-farmer irrigation.

Source: World Bank.

Building resilience to water shocks requires a multifaceted approach. This approach includes infrastructure development, such as water storage and flood levees, and inclusive policies and governance frameworks at the local, national, and international levels. These frameworks are crucial for effective coordination, resource allocation, and successful implementation of resilience measures (Browder et al. 2021).

Four key policy actions will directly empower poor and marginalized communities to weather extreme events: Set up robust and inclusive early-warning systems, establish insurance programs for weather risks, develop an inclusive strategy to mitigate flood risks, and scale up social protection schemes for vulnerable communities impacted by floods and droughts. These policy actions highlight the need to address the specific needs and unique vulnerabilities of marginalized communities at every stage of disaster risk management.

SET UP ROBUST AND INCLUSIVE EARLY-WARNING SYSTEMS

To improve water management practices and early-warning systems, governments should prioritize investments in data collection and in preparing relevant institutions to identify flood and drought impacts and those most affected by them (Beukes 2015). Data plays an important role in monitoring

BOX 5.1 Fast Track Water Security and Climate Adaptation World Bank Global Challenge Program

The World Bank is evolving its ambition and strengthening its finance and knowledge solutions to help countries tackle global challenges and achieve the Sustainable Development Goals by 2030. The ***Fast Track Water Security and Climate Adaptation Global Challenge Program*** (Water Global Challenge Program) is one of six pilot programs that will use replicable and scalable approaches to support countries in addressing development challenges with greater speed and impact. The Water Global Challenge Program will scale up support for water solutions through three interdependent pillars and a cross-cutting theme:

Pillar 1: Increasing access to safe drinking water, sanitation, and hygiene. Aiming for universal access, this pillar will promote circular economy practices in water supply and sanitation to address climate goals. It involves policy reforms, utility modernization, private sector engagement, innovative water solutions, and climate-resilient sanitation.

Pillar 2: Improving access to climate-resilient irrigation services and water productivity. This pillar will enhance climate-resilient irrigation services to boost food production and water efficiency, countering climate, competing demands, and demographic pressures. It will rely on expanding sustainable irrigation in underdeveloped areas. Other key interventions to be supported are adopting advanced technologies and empowering women in agriculture, with a focus on governance and private sector involvement.

Pillar 3: Building climate resilience and improving water resource management, including flood and drought risk reduction. Targeting climate resilience, this pillar will focus on sustainable water management to mitigate flood and drought impacts and protect vulnerable populations. Key interventions that will be supported include integrated planning, risk reduction, and nature-based solutions to manage water resources for growth and development without conflict or harm to livelihoods and the environment.

Cross-cutting theme: Enhancing water security in fragile, conflict, and violence-affected (FCV) settings for peace and stability. Water insecurity and climate change impacts are a destabilizing force and risk multiplier, particularly for women, in FCV settings, which are characterized by underlying fragilities, conflict, forced displacement, and weak or absent institutional capacity and policy buffers. This cross-cutting theme will emphasize institutional capacity building, private sector participation, and a shift from a humanitarian to a development approach in water resource management. The focus is on sustainable and climate-resilient water supply, sanitation, and irrigation service provision as well as on inclusive decision-making.

The Water Global Challenge Program will rely on broad regional coalitions and strategic partnerships as well as on political leadership and the capacity to generate broad public support for reforms. The program will bring global, regional, and country-level stakeholders together to co-create innovative solutions, support reform processes, and ensure fast-tracked implementation, including the mobilization of grants, concessional resources (including climate finance), and commercial financing.

The Water Global Challenge Program will be supported by the ***Global Water Security and Sanitation Partnership***, a multidonor trust fund that helps countries strengthen their policies, institutions, and regulations; scale up investments in water infrastructure and services; and manage water in ways that promote green, resilient, and inclusive development through World Bank projects. It will also be supported by the ***2030 Water Resources Group***, a global public-private partnership aimed at leveraging private sector capacities, resources, and solutions.

and understanding water shock risks. Data on these risks has historically been available mostly for high-income countries. Recent advances in the development of global water risk data can fill the gaps (Lindersson et al. 2020; Trigg et al. 2021). However, barriers to institutional capacity may limit some data applicability in low-income countries (Bernhofen et al. 2022).

In addition to data collection, early-warning systems are vital for increasing preparedness. Rough estimates suggest that universal access to such systems could reduce global well-being losses by $22 billion each year (Hallegatte et al. 2017). Implementation of robust early-warning systems requires investment in and maintenance of hydro-meteorological services, weather forecasting, and communication systems. To provide equitable benefits, warnings must be properly communicated and must reach low-income communities.

The design of early-warning systems should reflect inclusivity principles, that is, consider the economic damages and risk exposure of the poor, the disabled, and marginalized groups. This approach ensures more effective planning and response systems (GFDRR 2017). For example, the World Bank supported the Haitian government to develop innovative ways to communicate disaster warnings, including alert bulletins in local languages and through novel mediums such as music, radio, and social media (World Bank 2020b). These warnings have spurred responsiveness to hurricanes.

DEVELOP INSURANCE PROGRAMS FOR WEATHER RISKS

Chapter 4 reveals that uninsured weather risk persistently affects household investment behavior, even if the extreme weather event never materializes. Providing climate risk management instruments is, therefore, important not only for protecting people from direct losses caused by extreme hydro-climatic events but also for preventing indirect and often more significant losses arising from suboptimal investment decisions.

When households increase their access to climate risk management tools, there is a 15 percent to 30 percent surge in investment in agricultural inputs, irrespective of whether any climate shocks occur.[1] In Ghana, for instance, spending on agricultural inputs rose by 88 percent, from $375 to $705; in Mali, spending on agricultural inputs increased by 14 percent (Elabed and Carter 2015). The returns to these agricultural inputs vary depending on weather conditions, markets, and prices in any given year (Rosenzweig and Udry 2016), but even assuming a relatively low average return on input use, such increases translate to an average income growth of 1 percent to 9 percent per year. This growth is enough to lift many farmers out of poverty and to offset their losses associated with a one-in-five-year water shock.

However, the poor are systematically underinsured. Rural societies often depend on informal insurance, which is not well-suited to insure the aggregate risks due to erratic rainfall (Udry 1994). Even when formal insurance products are available, uptake remains low among low-income households, often due to liquidity constraints or a lack of trust in or understanding of the product (Carter et al. 2014). Developing climate insurance markets is a long-term task, but assessing the feasibility and functioning of those markets is an important short-term step.

Encouraging higher uptake of climate risk insurance requires marrying innovative solutions with policies that lower entry costs for smallholder farmers in low-income countries. Solutions such as index-based weather insurance work by directly tying payouts to an objective, measurable weather-related index.[2] It involves lower transaction costs and is more affordable than conventional insurance schemes (Hazell et al. 2010). Programs aimed at improving farmers' financial literacy and building trust can increase the adoption of insurance products (Gaurav, Cole, and Tobacan 2011). Hill, Robles, and Ceballos (2016) found that increased trust in insurance agents and training to improve knowledge about insurance products increased adoption of insurance among smallholder farmers in rural India. Dercon et al. (2014) found that training on risk-sharing policies targeted at community leaders resulted in considerably higher levels of rainfall insurance uptake within communities in Ethiopia. Partnering with a local NGO or micro-finance institution can also help build trust and increase access to marginal farmers (Aheeyar et al. 2019).

DEVELOP AN INCLUSIVE STRATEGY TO MITIGATE FLOOD RISKS

This report highlights a key factor that contributes to the strong association between poverty and increased exposure to flood risks in urban areas: with limited financial resources, many low-income families are forced to reside in informal settlements that are prone to flooding. Policies can address this challenge by encouraging construction of more affordable formal housing and by providing financial assistance to low-income households to help them move out of informal settlements (Satterthwaite et al. 2020). In Indonesia, for example, the government provided grants to help households living in flood-exposed informal settlements purchase land and build homes in safer locations.

When relocation is not an option, governments can support upgrading of informal settlements to improve access to critical infrastructure and enhance the safety features of home construction. In Argentina, for example, settlement upgrading programs were combined with the regularization of land tenure for inhabitants (Almansi 2009). Improving the security of land tenure for people living in informal settlements encourages homeowners to invest in property resilience upgrading (Hallegatte et al. 2017).

Policies such as risk-sensitive land use regulations that prevent house construction in flood-prone areas can further reduce the exposure of the poor to potential flood risks (Winsemius et al. 2018). In Ho Chi Minh, zoning controls were proposed to ensure that future low-income housing developments were located outside flood-prone areas (Adnan and Kreibech 2016). The success of such policies, however, are highly dependent on the strength of the institutions that implement them (Sudmeier-Rieux, Ash, and Murti 2013). Such policies also need to be carefully implemented to reduce unintended consequences, such as increased housing prices (Hallegatte et al. 2016).

Flood risks can be further mitigated through investments in traditional large infrastructure such as flood protection embankments, levees, and dams. However, conventional risk analysis approaches that are used to evaluate and plan such investments often exclude the poor and marginalized groups. Conventional approaches that rely on traditional cost-benefit analyses prioritize the protection of high-value assets and, therefore, are biased toward protection of high-income communities. Fully capturing the social benefits of climate risk management to achieve equitable access to and protection through infrastructure will require moving beyond traditional cost-benefit analyses and instead accounting for the relative well-being impacts of investments (Kind, Wouter Botzen, and Aerts 2017; de Bruijn et al. 2022).

SCALE UP SOCIAL PROTECTION SCHEMES FOR VULNERABLE COMMUNITIES IMPACTED BY FLOODS AND DROUGHTS

Social protection schemes and programs are important mechanisms to help the poor recover from shocks. However, if agencies in charge of running social protection schemes are not fully funded and trained, the scalability of flood and drought damage compensation can become inequitable. In Latin America and the Caribbean, many countries have successfully implemented social protection schemes. However, coverage gaps, low spending, and limited adequacy in some countries have left millions excluded from the schemes. The result is a missed opportunity to leverage those systems to broaden the scope of social protection. In the context of resilience to water shocks, adaptive social protection schemes have been developed separately from pro-poor programs and social protection schemes. This approach has increased the cost of enhancing the resilience of the poor to climate shocks and has threatened the financial sustainability of such schemes. Integrating disaster risk management with social protection schemes can reduce costs and allow marginalized groups to be assisted according to their needs. Innovative approaches such as anticipatory cash transfers are effective in reducing asset losses and future earnings losses after a flood.

Contingency funds help poor farmers adapt to the impacts of climate change on crop yields. These types of funds provide direct financial support in the event of poor harvests, ensuring stable incomes. To assist the poor, such funds subsidize crop insurance premiums, support the expansion of microfinance services to smallholder farmers, and finance technical assistance programs to implement climate-resilient agricultural practices. Additionally, investments from the funds usually expand infrastructure, such as irrigation, directly benefiting poor communities.

IMPROVING WATER RESOURCES DEVELOPMENT, MANAGEMENT, AND ALLOCATION

As discussed in Chapters 2 and 3, the growing global demand for water resources, coupled with climate change and environmental degradation, has increasingly put pressure on water availability and quality. Those conditions are making the efficient and equitable distribution of water resources more challenging. Effective water resources development and management and coordinated water allocation are essential to ensure equitable access to water resources. Three policy actions are recommended to improve water resources development, management, and allocation so that the poorest are not excluded and water resources are not overexploited: integrate nature-based solutions into water resources management, provide incentives and facilitate information sharing to enable cooperation on and coordination of water allocation, and adopt water accounting to inform water allocation decisions.

INTEGRATE NATURE-BASED SOLUTIONS INTO WATER RESOURCES MANAGEMENT PROGRAMS

In an era of unprecedented environmental and ecosystem degradation, a new paradigm for environmental restoration is needed globally. Integrating nature-based solutions into water resources management and disaster risk reduction policies, strategies, and investment programs is a critical step for restoring entire ecosystems. Doing so can also promote equitable access to water resources and water services.

Nature-based solutions can deliver a range of ecosystem services: (1) filtrating water pollutants, which benefits communities relying on natural water sources to satisfy their day-to-day water needs; (2) restoring watersheds and water-dependent ecosystems, which benefits rural communities that rely on agriculture and water-dependent ecosystems for food security and livelihoods; (3) storing excess water to reduce the incidence and severity of floods, which affect more poor communities settled in flood-prone areas; and (4) regulating water supplies, making it available during dry periods and benefiting poor communities dwelling in drought-prone areas.

Nature-based solutions are cost-effective because they enhance climate-risk adaptation through natural processes, even though quantifying some ecosystem service benefits is challenging. In Ethiopia, implementing sustainable land and water management practices has increased land productivity, avoided soil erosion, enhanced wealth, and diversified livelihoods for rural farmers. These interventions showed a rate of return of around 22 percent because of their high economic and environmental benefits and their low implementation and maintenance costs (Independent Evaluation Group 2020).

In other parts of Ethiopia, sustainable land and water management practices resulted in better soil fertility and moisture retention, increasing resilience to climate change (Bayle and Muluye 2023). Large-scale reforestation in Addis Ababa, Ethiopia, is delivering hydrological benefits by increasing runoff retention between 2.4 percent and 9.3 percent annually (Cutler, Gouett, and Guzzetti 2022).

Forest protection in the Chindwin River basin in Myanmar reduced average yearly losses to poor families by about 14 percent by simultaneously reducing peak discharge, flood volume, and flood extent (Lallemant et al. 2021). In Somalia, a sand dam and a weir built into the riverbank reduced the economic damages of flash floods between 38 percent and 60 percent and increased aquifer recharge along the river by 23 percent (UNEP 2022). These examples demonstrate how nature-based solutions can effectively mitigate the impacts of water-related disasters and increase the resilience of vulnerable communities.

Nature-based solutions are generally more accessible to poor and vulnerable populations when existing built infrastructure cannot be extended to remote areas. In some cases, they are less expensive than traditional "gray" infrastructure and offer additional benefits, including climate change resilience. Moreover, nature-based solutions offer more opportunities to increase the participation of vulnerable groups in decision-making processes to implement and maintain them (UNEP-DHI Centre on Water and Environment and IUCN 2018; IPCC 2022).

Despite the numerous advantages of nature-based solutions, their implementation is still limited. One barrier is the lack of awareness and understanding of the benefits of nature-based solutions among project developers and policy makers. Research efforts need to continue capturing evidence on the socioeconomic benefits of nature-based solutions to demonstrate their economic efficiency (Yee-Batista et al. 2023).

Another barrier to the implementation of nature-based solutions is funding. Although these solutions are cost-effective in the long term, they often do not generate immediate benefits to cover upfront investment and maintenance costs. Scaling up innovative financing arrangements, such as payment for environmental services (PES), can help address the funding gap. PES programs facilitate payment from users of ecosystem services to the landowners or communities providing the services so as to compensate them for maintaining the ecosystem (White et al. 2021). Emerging evidence shows that PES programs can satisfy environmental objectives while reducing poverty and improving communal social capital (Alix-Carcia et al. 2018; Jing and Du 2022; Vorlaufer et al. 2023).

Designing and implementing effective nature-based solutions requires robust knowledge about potential trade-offs. A recent review of these solutions in Africa reveals that reforestation and land regeneration can reduce the risks of floods and sediment loads but may reduce water resource quantities, potentially increasing the risks of downstream water scarcity (Acreman et al. 2021). Complementary policies are needed to mitigate such trade-offs.

PROVIDE INCENTIVES AND FACILITATE INFORMATION SHARING TO ENABLE COOPERATION ON AND COORDINATION OF WATER ALLOCATION

Water transcends the boundaries between countries, communities, and sectors; therefore, coordination and cooperation are essential for achieving sustainable and equitable water resources management and for preventing conflicts. Cooperation and coordination in water resource management can take various forms, including collaboration among water users or sectors, spatial or geographic coordination, and basin-level cooperation, including transboundary collaboration.[3]

As discussed in this report, rapid urbanization is prompting growing coordination of water supply and service delivery across the rural-urban spectrum (Garrick et al. 2019). Regional coordination involves water supply and service delivery models that connect irrigation and rural water supply providers with urban water utilities and informal or off-grid water vendors. Stronger regional coordination for water management can significantly benefit both cities and their surrounding areas. Collaborative efforts can reduce service delivery costs and ensure a more equitable distribution of water resources, mitigating the risk of water shortages. Conversely, a lack of cooperation on regional planning can have detrimental consequences, particularly for rural and peri-urban areas. Lack of coordination can manifest as permanent water diversions away from agriculture, hindering food security, or access to infrastructure access only in the urban core (Pearsall et al. 2021).

Effective transboundary water cooperation hinges on robust legal and institutional frameworks as well as mechanisms for information sharing and trust building. Transboundary cooperation helps countries understand their exposure to and impact on transboundary water issues, which is key to managing risks.

Coordination is costly, however, and coordination problems limit cooperation even when all parties can prosper through integrated management of regional water systems. These problems stem in part from information asymmetries and the high transaction costs associated with working across ministries, linking informal water providers and water utilities, and aligning different levels of governance (Villamayor-Tomas 2019).

Information gathering and sharing offer a starting point for joint decision-making and management of regional water supply. For example, hydrologic models paired with monitoring devices have allowed water utilities in South Africa to optimize storage levels in dams and reservoirs, demonstrating the value of data to improve the distribution of water resources to water supply networks. Remote sensing technologies can also promote transboundary water cooperation by providing information useful for flood forecasting, surface water quality monitoring, water diversion and allocation tracking, and water storage quantification in reservoirs. Such evidence changes the way in which different users value water. The Water Data Revolution project, supported by the Cooperation in International Waters in Africa program managed by the World Bank, aims to bridge the data gap in transboundary water management in Africa by providing water managers with remote sensing data tools. The project has conducted an assessment with 15 river basin organizations in 37 African countries, identifying data needs and challenges such as financial and technical constraints. Key outcomes include the development of tailored remote sensing data products and analytical tools to help organizations manage flooding and drought data more effectively, as well as capacity-building initiatives to enhance the use of data in light of organizational constraints.

In addition, the establishment of country and subnational financing platforms with common objectives of addressing climate risks and reducing socioeconomic exclusion can stimulate the participation of relevant actors, align stakeholders' interests, and support solutions for more efficient allocation of water resources. Some countries have established financing mechanisms like water funds to finance various water resources management initiatives.

ADOPT WATER ACCOUNTING TO INFORM WATER ALLOCATION DECISIONS

Basin-scale water accounting can ensure efficient and equitable allocation of water resources among competing sectors. Water accounting provides evidence to advance understanding of water's social, economic, and environmental value and to identify trade-offs among competing water uses. With information on water use, productivity, and the value added in different economic sectors within national accounts systems, the relevant parties can make efficient and equitable water allocation decisions, especially under changing conditions and scenarios, including those reflecting climate variability and change.

Water accounting systems inform decision-making in water allocation by fairly balancing the needs of all users, promoting transparency, and ensuring that water is distributed equitably and that all water users are held accountable. Additionally, water accounting can help identify sectors and areas, including ecosystems in a given water basin, with critical water needs. It can facilitate monitoring of water use, overextraction, and environmental degradation. Water accounting can also help resolve water conflicts, providing a factual basis for negotiation and evaluation of equitable solutions. Combining water accounting with economic and social data can help ensure that the economic, environmental, and social value of water is considered in decisions about allocations and evaluation of trade-offs.

IMPROVING EQUITABLE AND INCLUSIVE ACCESS TO WATER SERVICES

Achieving the high-level goal of equitable and inclusive water security will also require significantly larger investments and financing to address existing gaps. The aggregate investment/financing shortfall needed to achieve global water security by 2030 has been estimated at $6.7 trillion and $22.6 trillion by 2050 (World Water Council and OECD 2015). In many countries, current levels of funding—including revenues from customers, fiscal transfers, and grants—are not enough to meet basic operation and maintenance costs, resulting in significant underinvestment in infrastructure and leading to asset deterioration, poor service quality, and inefficient operations. Climate change is increasing the risks and amplifying water security financing gaps.

EXPAND ACCESS TO SAFELY MANAGED WATER SUPPLY AND SANITATION

As illustrated in this report, efforts are needed to reduce inequalities in the provision of safely managed water supply and sanitation. Much of the required coverage expansion needs to be targeted to poor and marginalized households in urban slums and rural areas as well as to school and health facilities. Five key policy actions could close the access gap.

Scale up financing through institutional and tariff reforms

A major barrier to expanding water supply and sanitation coverage in low-income countries is limited access to financing. Achieving universal access to safely managed water supply by 2030 will require six times increase on average in current rates of progress (14 times more in LDCs and 19 times more in fragile contexts). For safely managed sanitation, investments must increase five times more (16 times more in LDCs and 15 times more in fragile contexts) to achieve SDG 6 (United Nations 2023). In addition, the gap in public spending per capita between rich and poor countries for water and sanitation access is about 134 times larger (Joseph et al. 2024).

The aggregate investment/financing shortfall needed to achieve global water security by 2030 has been estimated at $6.7 trillion and $22.6 trillion by 2050 (World Water Council and OECD 2015). In many countries, current levels of funding—including revenues from customers, fiscal transfers, and grants—are not enough to meet basic operation and maintenance costs, resulting in significant underinvestment in infrastructure and leading to asset deterioration, poor service quality, and inefficient operation. Climate change is increasing the risks and amplifying water security financing gaps.

To scale up financing for the water sector, it is essential to ensure that public funds are used efficiently and to increase the overall funding available by mobilizing private financing (World Bank 2023). Governments can focus on the following set of actions:

(1) Reform water tariffs and subsidies while ensuring affordability and social protection for the poor and vulnerable.

In most countries, the price of water is not reflective of the cost of providing services, nor does it take into account the required capital investment needed to address aging infrastructure, climate impacts, demographic and demand shifts, and externalities caused by water pollution. Subsidies are frequently poorly targeted and nontransparent, leading to inefficacy in assisting the poorest and most vulnerable (Damania et al. 2023). Below cost-recovery tariff can result in a decline in financial performance and lack of creditworthiness of water utilities.

Introducing cost-recovery pricing mechanisms and reforming current water subsidy schemes can enhance the financial sustainability of water utilities, unlocking access to financing from commercial and private sources. New knowledge and technology are necessary to design well-targeted, transparent, and cost-effective subsidies (Andres et al. 2019). Furthermore, creating a supportive political coalition, implementing a flexible communication strategy, and designing an exit strategy, where necessary, are key to achieving successful subsidy reform.

The reform should focus on targeting subsidies to expand access to affordable water supply and sanitation services. It is recommended to prioritize subsidies for nonnetworked and on-site services, especially in rural areas where most of the poor reside, and to implement demand-responsive approaches, alternative technologies, and microfinance loans. Additionally, efforts should be made to ensure that subsidies are effectively targeted to benefit the intended beneficiaries, particularly the poor. In most cases, affordability is best addressed by using complementary instruments, such as vouchers or rebates for the poorest households.

(2) Improve efficiency of service providers and public spending.

To improve water sector performance, governments and water agencies should implement programs aimed at reducing water losses, improving efficiency in water and energy use, lowering operating costs, generating more revenue through efficient billing and collection processes, conserving and recovering scarce water resources, and increasing resilience to climate risks. The private sector can offer valuable expertise to enhance operational efficiency, technical capacity, and manage complex infrastructure. Performance and output-based contracts have been successfully implemented in various regions, including the Middle East and Africa (Algeria, Oman, and Saudi Arabia), Latin America (Brazil and Honduras), and Asia (Armenia, Philippines, and Viet Nam).

Furthermore, governments and water agencies can improve the efficiency of public spending in the water sector, as many countries did not fully spend their existing budget allocations. Capacity weaknesses across the project cycle, such as in design, procurement, and contract management, resulted in 28 percent of funds going unspent (Joseph et al. 2024).

Institutional reforms and incentives for improved performance can take various forms, such as corporatizing water service providers, consolidating sub-national entities, and establishing shadow credit-rating programs, as has been done in Angola, Kenya, Türkiye, and Peru. Other examples include turning around the technical and financial performance of water utilities to enable them to issue bonds, as seen in Uruguay, and implementing reforms that involve private and commercial finance and expertise in water projects, as in Brazil, Indonesia, and Nigeria.

(3) Use blended finance approaches to diversify and expand the spectrum of finance solutions.

Governments can explore various options to mobilize additional financing for water-related projects, such as tapping into capital markets and commercial and private financing, in addition to traditional public and concessional financing. To achieve this, blended finance mechanisms can be utilized to combine both types of financing and diversify funding sources. This can include commercial debt, bonds, microfinance, public-private partnerships, and other sources. By reducing their reliance on public and concessional funding and attracting more private capital, governments can unlock new opportunities for funding. Blended finance and credit enhancements can also help to de-risk projects for investors and lenders.

Reform water information systems to target pro-poor investments and monitor equitable and inclusive progress

To reduce inequalities in access to safely managed water supply and sanitation, funding must increase by several folds, with pro-poor targeting mechanisms in areas with low coverage and high water stress. Integrated geospatial systems, which pair geospatial data with subnational poverty, can help decision-makers identify and tackle inequalities in access to water services. Evidence and information can also spur collaboration between communities and multiple layers of government.

Promote innovation in technology, finance, contractual arrangements and program design

Innovation in technology, finance, governance, and contractual arrangements is crucial for reducing the cost of water supply and sanitation options, closing the gap between limited financial resources and investment, and addressing issues encountered during implementation.

Smart water metering, new digital technologies, advanced sensors, and other technologies could lead to reductions in the cost of delivering water services to poor populations. Many projects financed by the World Bank support the development, testing, and siting of innovative water and sanitation technologies and business models. Regional centers of excellence have also been used to engage the operation and maintenance know-how of private sector service providers.

Countries have experimented with various programs to address access and affordability constraints. For example, in Dhaka, Bangladesh, regulatory and institutional reforms in the sector allowed Drinkwell, a social enterprise, to partner with mobile operator Robi Axiata and Dhaka's water utility, Dhaka WASA, to provide safe, affordable water to informal settlements through a network of water vouchers. In response to the COVID-19 pandemic, Drinkwell leveraged its distribution network in informal settlements and partnered with a mobile hygiene station provider, Happy Tap, to expand handwashing services to poor customers (Bauer 2020). This partnership has been instrumental in preventing the spread of infectious diseases.

Similarly, programs in Tamil Nadu (India), Salvador (Brazil), and Nairobi (Kenya) have made sewerage connections affordable to low-income households by allowing them to pay for the sewerage connection fee in installments over a relatively long period (Kennedy-Walker et al. 2020). In addition, many water utilities in Sub-Saharan African countries have partnered with domestic private providers to extend water services to the urban poor through feeder market innovations such as regulated water vending, pay-and-use toilets, and private operation and management of community taps (Independent Evaluation Group 2017).

Innovation in contractual arrangements has helped overcome technical challenges. In Tamil Nadu, India, for example, contractors have some freedom to determine alternative solutions for households that cannot connect to the sewerage system because of insufficient head pressure to carry the wastewater by gravity out of the premises into the collector. In Salvador, Brazil, contractors involved in the Bahia Azul sewerage investments in low-income communities had some flexibility to establish unconventional routes—condominium sewerage systems—for households located in informal and densely occupied settlements (Kennedy-Walker et al. 2020).

Innovation in program design can be effective in promoting behavior change. Dupas et al. (2023) assessed the impact of a program providing monthly coupons for free water treatment solutions in Malawi, showing large and sustained effects on water purification and child health. The study suggests that self-targeting through coupon redemption is more effective than targeting by community health workers, highlighting the potential for coupon programs within "well baby" schemes as a scalable approach to reduce waterborne diseases.

Many technological and financial innovations are within reach but remain at the pilot stage and have not been mainstreamed. Thus, governments can play a critical, but often ignored or underplayed, role in creating an environment that supports innovation. The governance of the water supply and sanitation sector—that is, the sector's laws, policies, regulations, institutions, and systems—is critical to scaling up and mainstreaming technical and financial solutions (World Bank 2022).

Improve transparency and accountability of water institutions

Achieving equitable and inclusive access to water supply and sanitation services requires appropriate accountability mechanisms and the effective participation of beneficiary groups. This participatory governance approach empowers local communities to participate in discussions of critical issues such as pricing policies and affordability. Experience from the municipal water sector illustrates the importance of this political economy perspective of ensuring that poor households are fully involved in the decision-making process. For example, a key component of the strategy that led to the remarkable transformation of the Phnom Penh water supply utility in Cambodia was that poor households were mobilized to support the utility's efforts to expand services and charge higher prices for water (Biswas and Tortajada 2010). Ek Sonn Chan, the utility director, had to deliver a petition signed by thousands of poor households to convince senior government officials that it was "safe" for them to authorize a water tariff increase (Leong 2010).

Participatory approaches empower marginalized groups to take ownership of water supply and sanitation services and to ensure their specific needs and concerns are addressed. In Indonesia, the government partnered with an organization of persons with disabilities to provide disability-inclusive WASH services through its flagship, nationwide, community-driven WASH program, PAMSIMAS (World Bank 2015) (see "Spotlight: Indonesia's Water for Shared Prosperity Initiatives"). The effort involved developing and adopting accessibility guidelines and designs, building accessible infrastructure, and consulting with and engaging persons with disabilities in project planning and implementation. As of 2021, the program had provided accessible WASH services to nearly 200,000 people with disabilities.

In Brazil, SABESP, the water supply and sanitation utility of the city of Sao Paulo launched a multipronged program in 2017 called "Se Liga na Rede (Connect to the Network)," targeting about 300,000 households in low-income areas receiving access through illegal connections. The program formalized water supply and sanitation services to the poor through pro-poor targeting strategies in urban slums. It promotes social participation and enables social monitoring of new connections to poor households, including participatory planning, socio-technical engagement to build new connections, incentives to move connections from illegal to legal arrangements, and access goals for areas of social vulnerability. As a result of the program, legal connections to water and sanitation services have increased by 10 percent (IBGE 2021).

Despite their benefits, participatory processes can have downsides (Banerjee et al. 2010; Chukwuma 2016; Walker, Smigaj, and Tani 2021). They include the risk of tokenism, whereby community members are included in decision-making processes, but their input is not taken seriously or acted on, which can undermine the effectiveness of the participatory approach. Additionally, participatory processes can be time-consuming and resource-intensive, requiring significant investment in capacity building and facilitation. There is also the potential for power imbalances within the community; certain groups or individuals may dominate the decision-making process, marginalizing others. Additionally, participatory processes can be susceptible to external influence or manipulation, particularly by powerful stakeholders or interest groups, which can compromise the integrity and inclusivity of the process. Finally, the challenge of sustaining collective action in large groups and the skepticism of community members about the effectiveness of traditional systems can hinder the impact of participatory processes.

Genuine and meaningful participation of community members requires creating an inclusive and empowering environment. This environment can be achieved through capacity-building initiatives to ensure that all participants have the knowledge and skills to engage effectively in the decision-making process. It is also crucial to establish clear guidelines and mechanisms for decision-making, ensuring that power dynamics are balanced and that all voices are heard. Transparency and accountability are key to maintaining the integrity of participatory processes, and mechanisms for feedback and grievance redressal should be put in place. Additionally, it is important to actively address tokenism and ensure that community input is valued and acted on. Furthermore, involving women and marginalized groups (including youth, the elderly, and indigenous people) in decision-making and project implementation can contribute to the functionality of the water systems. Women's participation has been found to be positively associated with system functionality (Daniel, Al Djono, and Iswarani 2023).

Enhance collaboration among institutions

Delivering universal access to safely managed drinking water and sanitation requires the strong collaboration of government agencies and institutions. Often, ministries of water or public works are responsible for the provision of drinking water, but the provision of safe water in rural areas relies on fragmented institutions and actors. Many ministries of health implement programs locally. Water institutions can collaborate with the health sector to make program implementation less fragmented and more effective.

Water treatment, for instance, is one of the most cost-effective interventions for reducing child mortality (Kremer et al. 2024). Provision of safe water requires treatment to reduce microbiological contamination. Improved water sources and piped systems reduce contamination, but contamination can still occur, including during the transport and storage of water (Cherukumilli et al. 2023; Kremer et al. 2009). Approaches to delivery of water treatment vary by context: where water is delivered from pipes or storage tanks, it can be treated through passive chlorination (Cherukumilli et al. 2022); where people collect water from wells or surface water sources, point-of-use water treatment can be delivered through the maternal and child health system (Dupas et al. 2016, 2023). Effective intervention to improve water treatment requires public health systems to integrate these interventions in their urban and rural programs (Dupas et al. 2016, 2023).

Delivering adequate water services to schools is also important to prevent interruption of children's education. Countries with well-established pro-poor programs can leverage education and social protection systems to improve pro-poor focalization of water interventions.

Lastly, effective coordination across ministries that influence urban growth is crucial to addressing the challenges of city water security. As explained in Chapter 2, the shape and structure of urban areas are closely connected to income, access to infrastructure and water, and social exclusion, with remote communities often facing higher poverty rates and more sprawling cities incurring greater costs for water services and struggling to ensure equitable access. This reality underscores the importance of developing tailored urban planning strategies that aim to avoid haphazard and disorganized growth while promoting sustainable and inclusive development.

ENHANCE AGRICULTURE WATER MANAGEMENT

This report has highlighted how irrigation has become a key factor for modern food production, leading to a range of benefits such as poverty reduction, livelihood enhancement, and overall social development. All of these benefits have contributed to the promotion of shared prosperity. However, lessons from the past 75 years have also shown that the benefits and costs of irrigation are not evenly distributed across and within countries. Smallholder farmers and impoverished communities are often the ones who face the brunt of the challenges associated with irrigation systems. At the same time, the need for irrigation as an adaptation mechanism for a changing climate is only growing. As climate change increases the variability of precipitation in both time and space, irrigation holds one of the keys to maintaining stability in both local food production and global agricultural markets.

If it is to continue contributing to shared prosperity for the next century, irrigation cannot be driven by the expansion model of the past. Instead, it requires a new approach that focuses on broad agricultural water management and policy change. Three key policy actions for agricultural water management would increase productivity and sustainability in a new water era and ensure that benefits are distributed fairly among all stakeholders: broaden the intervention from irrigation to agricultural water management, promote decentralized water management for agriculture, and expand innovation to benefit the poor.

Expand the scope of the intervention from irrigation expansion to a more comprehensive approach

Achieving equity in the use of water in agriculture requires not only irrigation expansion but also sustainable agricultural water management in general. Although the benefits of irrigation are clear, surface irrigation, by its nature, will always be highly concentrated in a subset of agricultural lands, with gross inequities in access within and among countries. On the other hand, groundwater-based irrigation systems are accessible to a wider range of areas. However, the open-access nature of most aquifers has made groundwater use extremely difficult to govern. The result has consistently been unsustainable use rates, falling groundwater tables, increasing energy costs as water is pumped from ever deeper levels, and inequitable outcomes as those with the least capital lose the race to the bottom. The difficulty of finding ways to govern agricultural groundwater use often causes permanent reductions in storage capacity, forestalling its significant potential as a climate adaptation tool.

Other complementary approaches to agricultural water management can be less spatially exclusive and have significant potential for improving agricultural productivity and shared prosperity. These approaches entail better management of soil, crops, and water to enhance productivity across all agricultural water management options, ranging from rain-fed agriculture to supplementary irrigation with water harvesting,[4] to full irrigation (Rockstrom et al. 2009).

In many cases, changes in crop water availability do not need to be substantial to be impactful. One study estimated that increased crop water availability for a single month would substantially raise output on 25 million hectares of land currently unirrigated either because surface water sources were unavailable or their development was uneconomic (Rosa et al. 2020). If crop water availability could be increased through interventions that reduced evaporation by 25 percent and collected 25 percent of runoff from rainfed lands, the impact would be similar in magnitude to that of existing irrigation (Rost et al. 2009).

These ideas are not new, and some have already been implemented under farmer-led irrigation. However, more can be done by government and other institutions to increase impact. As an example, training related to traditional irrigation is often separated from training for rainfed conditions. Rather than relying on existing production system definitions (irrigated versus rainfed), shifting to an integrated vision of agricultural water management that incentivizes sustainable water use could be a more equitable and sustainable approach.

Promote decentralized water management for agriculture

Ensuring equitable distribution of benefits from irrigation and agricultural water management is essential for promoting shared prosperity. Participatory irrigation governance models, such as decentralized and community-based management, have the potential to enhance the accessibility of irrigation to underprivileged communities by prioritizing inclusive, equitable, and sustainable management practices.

Decentralization transfers the authority and responsibility for water resource management from the central government to local or regional entities. Community-based management divides management responsibilities between government authorities and local communities or user groups. This type of management has the advantage of self-targeting the poorest rural residents, who are least likely to have traditional irrigation access. It relies on indigenous knowledge and practices, often governed by traditional laws and customs (see "Spotlight: Indonesia's Water for Shared Prosperity Initiatives"). In addition, the participatory approach empowers local communities and traditionally marginalized groups to be involved in decision-making about water allocation, maintenance of irrigation infrastructure, and financial management, ensuring that the system meets their specific needs and is more inclusive, equitable, and sustainable.

In Nepal, farmer-managed irrigation systems have empowered local farmers and strengthened local governance, leading to more efficient water use (Thapa et al. 2016).

In Pakistan, transferring irrigation management from a provincial irrigation department to farmer organizations improved the recovery of irrigation charges (Baig et al. 2009). The institutional reform paved the way for financial reforms, replacing the crop-based water charging scheme with an area-based water charging scheme whereby water charges were levied per unit area with differential rates for head- and tail-end clusters. The system increased irrigation charge recovery and crop yields.

However, not all participatory irrigation management models have yielded anticipated benefits (Senanayake, Mukherji, and Giordano 2015). The models' effectiveness depends on adaptability to local contexts, extent of stakeholder engagement, and commitment to addressing the specific needs and challenges of marginalized groups. To maximize the effectiveness of participatory approaches, such as water user associations, it has been recommended that they be organized based on hydrologic boundaries, with reduced overlap between their leadership and that of the villages. Additionally, it is crucial to support the water users' associations with the autonomy they need and encourage farmers to take an active role in the decision-making (Wang and Wu 2018).

Expand innovation to benefit the poor

Innovations in agriculture have improved food security but have not always benefited the poorest (Hyman et al. 2008). There is continued scope for crop improvement that enhances the livelihoods of the poor in marginal environments. Hence, it is crucial for the government to create a conducive policy environment for innovation and to encourage private investment that can ultimately benefit poor farmers.

Over the last two decades, private capital investment, including in genetic and agricultural research, has increased rapidly and now rivals that of governments. This investment has given rise to a nascent biotechnology revolution that is transforming agricultural research by accelerating trait development for crops and rapidly reducing development costs and time (Kalaitzandonakes, Willig, and Zahringer 2023).

These changes could foster the development of crops suitable for regions with high water variability and marginal rainfed conditions and where the rural poor are concentrated and traditional irrigation is not possible. For example, the genome editing and synthetic biology revolution, combined with artificial intelligence, is accelerating the rate of trait development for crops, allowing the development of novel traits related to crop water use, including drought, flood, and salt tolerance.

Although private investment will have significant impacts on agricultural productivity and water use, private capital typically gravitates toward the most profitable ventures, not necessarily the ones with the highest poverty-reducing potential. For example, although Africa had the highest concentration of rural poor and 95 percent of the world's rainfed lands in 2021, less than 2 percent of all private agricultural research and development capital flowed there.

Governments and the international community need to develop new strategies to help ensure that benefits from recent technological innovation will be shared with the poorest farmers in marginal environments. Governments can be supported in building nationally appropriate legal and institutional frameworks that facilitate private sector investment and competition in agricultural research that meets national agricultural and water priorities. One reason private funds have so far bypassed Africa is underdeveloped regulatory environments. Only 9 of 54 African states have or had the biosafety laws generally needed to underpin contemporary biotechnology research.

Government intervention is also needed to allow farmer-led and privately financed irrigation to flourish. Farmer-led and -financed irrigation often falls outside of official irrigation definitions and statistics. As a result, it is underappreciated and undervalued (Namara et al. 2010) despite its extensive scale (for example, private groundwater likely accounts for 40 percent of global irrigation water). This scale clearly shows the widespread profitability of private irrigation finance and development and the willingness of farmers to pay for irrigation services (Merrey and Lefore 2018; Lefore et al. 2019). The interventions needed from the state are thus not related to major infrastructure but rather to the creation of an enabling environment that enhances the possibilities for farmers to develop water resources on their own while managing potential trade-offs and conflict at the watershed or basin scale. These interventions include enhancing technology access, catalyzing smallholder value chains, and fostering supportive policies (Giordano and de Fraiture 2014).

CONCLUDING REMARKS

Achieving sustainable development, reducing poverty, building resilience, and addressing fragility all hinge on addressing inequality in water access and mitigating the impacts of hydro-climatic extremes. Effective water management is essential and requires strong political backing and elevation to a national priority. To translate water security into shared prosperity, water policies and interventions must be fully integrated into a country's economic strategies. This approach ensures that macro-economic actions support water security benefiting poor people directly and indirectly.

NOTES

1 This surge is based on evidence from Mobarak and Rosenzweig (2013) for rainfall index insurance in India; Elabed and Carter (2014) for area yield insurance in Mali; Karlan et al. (2014) for rainfall index insurance in Ghana; Cai, De Janvry, and Sadoulet (2015) for swine insurance in China; Cai (2016) for area-yield insurance in China; Fuchs and Wolff (2016) for rainfall index insurance in Mexico; Jensen, Barrett, and Mude (2017) for livestock insurance in Kenya; Hill et al. (2019) for rainfall and area-yield insurance in Bangladesh; Bulte et al. (2020) for multiperil crop insurance in Kenya; and Stoeffler and Opuz (2022) for area-yield insurance in Burkina Faso.

2 One of the main drawbacks of weather index insurance is that an index cannot perfectly represent the individual losses of an insured farmer, i.e., basis risk. Technological solutions—such as satellite-based yield predictions— contractual solutions—such as secondary, backup, or audit indices—and institutional solutions that involve state support and subsidies hold promise to make crop insurance more accessible and beneficial for smallholder famers.

3 Nobel Laureate Elinor Ostrom's theory of common-pool resource management provides valuable insights into the principles that underpin successful cooperation at all levels (Ostrom 2002). Ostrom's eight design principles are (1) clearly defined boundaries for the resource system and its users to avoid confusion and conflicts; (2) proportional equivalence between benefits and costs to ensure fairness and equity; (3) collective choice arrangements to give users the right to participate in the decision-making process regarding the rules and regulations governing the resource; (4) monitoring by the users or a trusted third party to ensure compliance with the established rules and to detect any violations; (5) graduated sanctions to discourage noncompliance with and encourage adherence to the rules; (6) conflict resolution mechanisms to maintain harmony and cooperation; (7) minimal recognition of rights to organize; and (8) nested enterprises, with multiple levels of decision-making and cooperation, from local to regional to global, to address different scales of resource management challenges.

4 For example, soil and water conservation practices such as terrace and no-till farming and rainwater use can augment base flow by increasing soil water storage capacity and, therefore, reducing irrigation requirements.

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Spotlight: Indonesia's Water for Shared Prosperity Initiatives

Indonesia's water sector is facing multiple challenges associated with rapid economic development, population growth, urbanization, and increasing competition between water users and water resources. Moreover, climate change, which is amplifying these challenges, is jeopardizing Indonesia's Vision 2045.

Indonesia Vision 2045: Towards Water Security (World Bank 2021) recommends that Indonesia take several actions to improve water insecurity and strengthen shared prosperity to help achieve Indonesia's goal of becoming the fifth-largest global economy by 2045, 100 years after Independence. The greatest benefits would come from universalizing water and sanitation coverage, improving water allocation efficiency for irrigation, and building water resilience. Those targets cannot be achieved without enhancing coordination of and cooperation among water management institutions and water users.

"Spotlight: Indonesia's Water for Shared Prosperity Initiatives" presents the distinct water security challenges faced by Indonesia and the country's innovative, home-grown, and often local community-led solutions. These solutions focus on expanding access to safe water, increasing water storage, improving water quality, and enhancing the quality of water services while promoting shared prosperity to make sure all boats are lifted simultaneously. Lessons from Indonesia's experience might inspire other countries to promote water security and shared prosperity.

This spotlight is organized along the three axes for action identified in this report (Figure S.1): (1) improve broad-based resilience to climate-related water risks (e.g. floods and droughts), (2) enhance resource management and allocation, and (3) promote more equitable and inclusive access to water services (i.e., irrigation and water supply and sanitation).

RESILIENCE TO CLIMATE-RELATED WATER RISKS

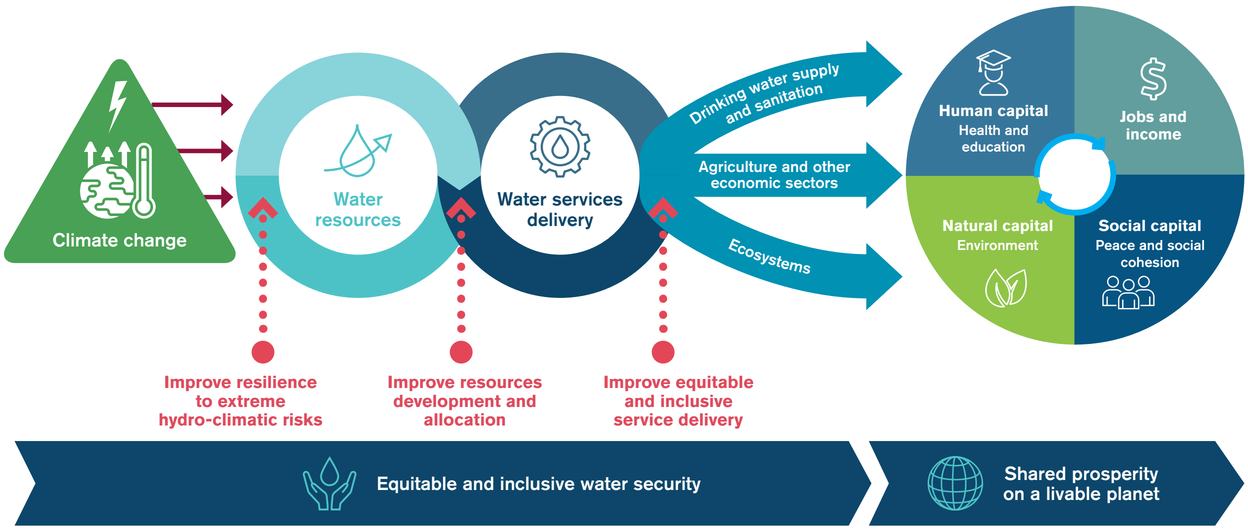
Promoting water resources development requires a renewed focus on broad-based resilience. Indonesia has made significant investments to enhance the water sector's resilience against climate-related water risks. These investments include a multipurpose water storage development and dam safety program and community-driven early-warning systems.

MULTIPURPOSE WATER STORAGE DEVELOPMENT AND DAM SAFETY PROGRAM

With a population of roughly 274 million, Indonesia is the world's fourth-most-populous country.[1]The country faces significant challenges in meeting its water needs. Java Island, the world's most densely populated island, with 1,015.9 people per square kilometer, provides a daunting example of these challenges. The need for comprehensive and sustainable water management practices is crucial as the country grapples with the complexities of balancing population growth, environmental preservation, and resource use against the backdrop of climate change.

With climate change and precipitation becoming more volatile, responding to changes in rainfall and river runoff becomes increasingly important. Developing new storage systems and better managing existing ones while ensuring their safety is a critical climate change adaptation strategy. However, Indonesia's water storage capacity (62.7 cubic meters per capita) is below that of countries with similar seasonal variability, such as Malaysia (710 cubic meters per capita) and Japan (228 cubic per

FIGURE S.1 Conceptual framework of *Water for Shared Prosperity*



Source: World Bank.
Note: Water security is defined as the availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems, and production, coupled with an acceptable level of water-related risks to people, environments, and economies (Grey and Sadoff 2007). Water services include irrigation, water supply, and sanitation.

capita). Only 8 percent of the country's hydropower potential has been developed, and the Government of Indonesia has set a visionary target of 31 percent of renewable energy in the national energy mix by 2050.

To better adapt to climate change, the government has embarked on an ambitious program to expand water storage capacity to 3.8 billion cubic meters by developing 61 new dams (Figure S.2). Those dams will increase per capita storage capacity to 76.7 cubic meters. In developing these new dams, the government has adopted a multipurpose approach to leverage water storage for hydropower, water supply and irrigation, environmental services, and flood control. The 61 dams will increase the area irrigated by dams from nearly 700,000 hectares to nearly 1 million hectares. They will provide 45.43 cubic meters per second of raw water, reduce flood volumes by 13,000 cubic meters per second, increase hydropower generation capacity to 256.4 megawatts, and expand floating solar power generation capacity to 4,760 megawatts.

Multipurpose dams optimize the value of stored water and reduce the risks of water stress during the dry season. The introduction of improved reservoir management reduces overexploitation of water resources. When multiple reservoirs are sited in one river basin, a cascade management approach is implemented to seize additional benefits and distribute them fairly. Furthermore, multipurpose benefits can be captured by investing in tourism, hydropower, floating solar energy, and fisheries solutions. In many cases, the revenues generated from these investments can offset the costs of operating and maintaining downstream irrigation systems. Moreover, they can attract private sector investors through hybrid annuities raised with design-build-operate-transfer contracts specifying performance-based rewards for operation and maintenance activities.

Multipurpose dams could contribute significantly to the nation's agricultural productivity, energy security, and disaster mitigation efforts. They have become even more critical as the frequency of tropical cyclones and other extreme weather events has increased. La Nina and El Nino phenomena are augmenting these events. Figure S.3 shows radiation observations based on Himawari-9 infra-red enhanced satellite imagery made at a wavelength of 10.4 micrometers. Orange and red areas indicate significant cloud growth with the potential to trigger the formation of cumulonimbus clouds, which are the seeds of cyclones. Changes in rainfall intensity can lead to flood and drought, making it crucial to implement rigorous dam safety and operation management practices to safeguard both lives and resources.

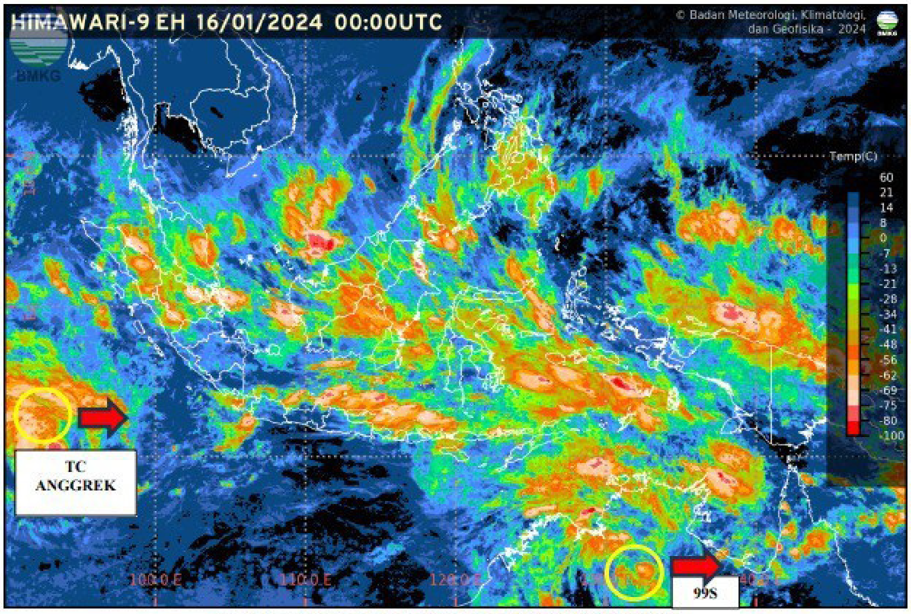
The Government of Indonesia, with the World Bank and the Asian Infrastructure Investment Bank, implemented the Dam Operational Improvement and Safety Project (DOISP) to address dam safety concerns. Because of those concerns, water levels in the associated reservoirs have been kept low, diminishing dams' capacity to buffer the effects of climate change and increasing hydrological variability. By improving dam safety, the DOISP increased dam operating capacity, reducing flooding and increasing water supply in dry seasons. The project implemented structural measures to rehabilitate spillways, create multifunctional intakes, increase dam height (with parapets) as well as nonstructural measures to run hybrid reservoirs, adopt early releases for flood control during the rainy season, and optimize operations by adding climate parameters, seasons, and weather phenomena to the rule curve (Figure S.4).

DOISP is helping communities become more resilient by investing in upstream catchment activities. These activities are designed to reduce erosion, which is expected to intensify because of climate change. Community participation activities, with a total actual cost of $2.3 million, have been conducted at 34 dams. Activities included planting productive (fruit) trees around reservoirs and in water catchment areas. More than 67,000 hectares have successfully been rehabilitated in the Citarum catchment.

FIGURE S.2 Construction of 61 multipurpose dams

Source: Government of Indonesia.

FIGURE S.3 Severity of cyclones in Indonesia



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Source: BMKG Indonesia (2024).

FIGURE S.4 Structural adaptations of dams

a. Ubrug spillway gate

b. Door operator post for flow regulation

c. Ground seal at Jatiluhur spillway

Source: Directorate of Dams and Lakes, Ministry of Public Works and Housing, Indonesia.
Note: (a) Spillway gates in dams serve a crucial function in managing the flow of water. They are primarily used to regulate the release of excess water from a reservoir when it reaches a certain level, preventing overflow and potential damage to the dam structure and downstream areas. (b) Dams are typically constructed with a drain mechanism to control water levels in an impoundment for normal maintenance or emergency purposes. When a flood occurs, operating doors regulate flows to avoid damage. (c) A ground seal is a structural adaptation option. A robust, waterproof seal penetrates deep into crevices and gaps.

Construction of new dams can bolster Indonesia's resilience against the impacts of climate change, but additional measures are imperative. They include establishing new safety protocols and technical standards for construction, modernizing existing dams by increasing flow regulation, harnessing storage in lakes and reservoirs, and capitalizing estuarine reservoirs.

COMMUNITY-DRIVEN EARLY-WARNING SYSTEMS

Worldwide, communities face threats of extreme weather events such as cyclones and flash floods. In addition, they encounter the protracted challenges of dealing with long-term phenomena such as droughts and gradual climate shifts. These challenges call for systems that are not only reactive but also predictive, harnessing local knowledge, scientific advancements, and technology to provide timely alerts and enable fast responses, appropriate actions, and effective preparedness strategies.

Climate-related early-warning systems can alert communities to imminent danger, facilitate evacuation, and orchestrate relief efforts. Moreover, they can play a critical role in helping communities manage risks in sectors vulnerable to climate variations, including agriculture. The growing focus on these systems worldwide indicates the need for more resilient, adaptable, and inclusive approaches to mitigate risks and prepare societies for the challenges posed by an increasingly unpredictable climate.

GRASSROOTS APPROACH TO DISASTER MANAGEMENT: TROPICAL CYCLONE SEROJA

To achieve inclusive and participatory approaches for hydro-climatic risk management, community-driven early-warning systems are crucial. Mohammad Mansyur, colloquially known as "Pak Dewa," implemented such an approach. During Tropical Cyclone Seroja, which devastated East Nusa Tenggara Province in April 2021, Pak Dewa, a fisherman, applied local knowledge of early-warning methods. Pak Dewa's deep understanding of the sea and weather patterns, honed through years of experience, allowed him to recognize early signs of the approaching Seroja—subtle changes in wind patterns, sea behavior, and cloud formations that were familiar to him and other local fishermen (Figure S.5). This valuable knowledge, combined with official alerts and information disseminated by the Indonesian Agency for Meteorology, Climatology, and Geophysics (BMKG), prompted fishermen to take proactive measures. Their informed actions led to the successful evacuation of his village, underscoring the effectiveness of community leadership and the synergistic power of integrating traditional knowledge with scientific advancements in crisis scenarios. Leveraging local knowledge and strong disaster preparedness systems enhances the resilience and safety of vulnerable populations.

WEATHER AND CLIMATE INFORMATION AND PREDICTION: SEKOLAH LAPANG IKLIM (CLIMATE FIELD SCHOOL)

In a different yet equally challenging context, the Climate Field School (CFS) program—developed by BMKG to empower farmers to intelligently access and use weather-climate information and predictions—offers an important case study.[2] The CFS program in Gunungkidul, Yogyakarta Province, showcases the impact of climate literacy on farming resilience. The program provided farmers with tools and data, such as real-time weather updates through a mobile app and climate-smart agriculture techniques, enabling informed agricultural decisions. Workshops taught farmers to interpret weather data to optimize planting and harvesting practices. The program also enhanced crop productivity

FIGURE S.5 Pak Dewa, together with the head of BMKG, elaborates on the importance of integrating community-driven early-warning systems into the media

Source: BMKG Indonesia (2024).

and economic stability, benefiting the entire community. The Climate Field School exemplifies how integrating scientific data with practical applications can build sustainable, resilient communities by harnessing the value of early-warning systems and response mechanisms in agriculture (Figure S.6).

Tropical cyclone Seroja in Gunungkidul highlights the effectiveness of community-driven early-warning systems. When the cyclone occurred, the community was able to use mobile technology for rapid dissemination of weather alerts to the most remote areas. Climate data and information enabled farmers to reduce crop damage by optimizing crop management during the event. Moreover, "last mile" communication strategies were vital. During the cyclone, motorcycle volunteers delivered warnings and supplies to isolated communities, ensuring critical information and aid reached the most vulnerable. These efforts underscore the value of integrating technology with traditional knowledge. By focusing on inclusivity and local expertise, such initiatives not only protect communities but also empower them to meet the challenges of climate change.

ENHANCE RESOURCE MANAGEMENT AND ALLOCATION

LAKE RESTORATION AND CONSERVATION

According to the Ministry of Public Works and Housing (MPWH 2019), Indonesia has 941 lakes. These lakes play multifaceted roles crucial to human life and the environment. They help balance ecosystems, offer invaluable services such as flood control, drought mitigation, climate change adaptation, and provide habitats for biodiversity. Additionally, lakes are significant hubs for ecotourism and educational endeavors. Recognizing their importance underscores the imperative of cross-sectoral coordination in their management, a pivotal measure for effective water resource allocation.

FIGURE S.6 Engagement with local farmers during Climate Field School in Gunungkidul

Source: BMKG Indonesia (2024).

Indonesia's lakes face mounting threats from human-induced pressures, including burgeoning population growth, intensified land use, and increased surface water use. Catchment areas, frequently allocated for agriculture, are particularly vulnerable to land erosion and water pollution. Downstream lakes bear the brunt of heightened sedimentation rates, water pollution, and eutrophication. These challenges cast a shadow over local and national socioeconomic conditions, exacerbating existing disparities and hindering sustainable development efforts.

The Indonesian government is supporting lake restoration and conservation. Actions include accelerated control of erosion damage, watershed preservation and restoration, and normalization of 15 national priority lakes to spur sustainable community welfare.[3] These lakes were designated priority lakes on the basis of the extent of their degradation; the extent of pressure on them; the strategic economic, sociocultural, and scientific value of their surrounding ecosystems; and their inclusion in development planning documents, master plans, or other technical documents in the water or lake sector.

POLLUTION CONTROL AND ECOLOGICAL RESTORATION: CITARUM RIVER BASIN

The Citarum River Basin plays a crucial role in the lives of millions of people in West Java and Daerah Khusus Ibukota Jakarta, the Special Capital Region of Jakarta.[4] The Citarum River contends with substantial industrial waste, agricultural runoff, livestock waste, fisheries byproducts, domestic refuse, and other contaminants. Population expansion and industrial and domestic activities along its banks have increased. The Citarum River was once infamous as the world’s most polluted river.

The Indonesian government has embarked on initiatives to tackle the pollution plaguing the Citarum River. Notably, it implemented Presidential Regulation No. 15 of 2018, designating the Citarum River Basin as a national priority river basin, underscoring the imperative to expedite pollution control and mitigation actions. This approach is far from top-down; instead, it fosters collaboration among diverse stakeholders, including the Indonesian military and other institutions and local communities and organizations, to holistically address the river’s challenges.

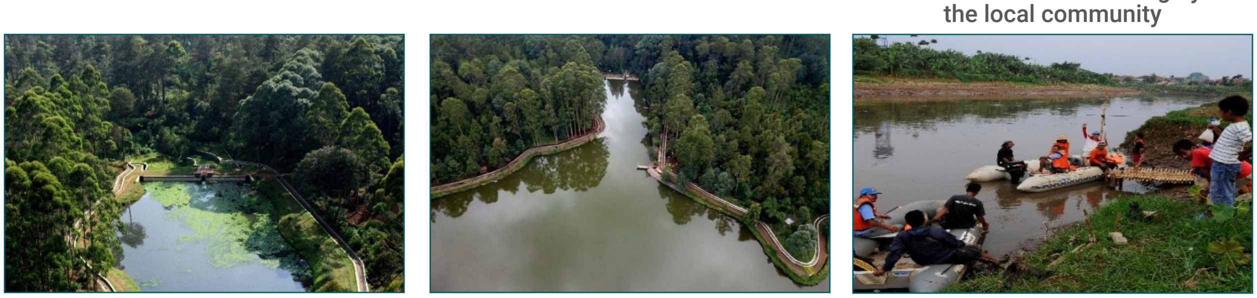
Efforts to address the river’s environmental degradation include the Critical Land Handling Program, which focuses on managing land conversion in degraded areas, and the Domestic Wastewater Management and Waste Management project. Other projects focus on industrial and livestock waste handling, law enforcement, and tourism management. Each contributes to restoration and maintenance of the Citarum River Basin and its surrounding ecosystem.

Recently, the river’s water quality index has significantly improved, riverbanks have been restored, public spaces have once again become functional, endemic fish populations have been revitalized, river cleanliness has increased, and flooding occurrences have been reduced. These accomplishments underscore the efficacy of the efforts aimed at combating pollution and environmental degradation within the Citarum River Basin (Figure S.7).

However, several challenges remain, including budget limitations, delays in infrastructure development, difficulties in monitoring and enforcement, and resistance from local communities. Therefore, there is a need to strengthen coordination among stakeholders, enhance the effectiveness of task forces, improve data accuracy, and prioritize pollution control in regional development plans. Sustaining progress requires transparency and accountability in governance, political will, and community engagement.

FIGURE S.7 Upper Citarum River community-based cleaning and land rehabilitation

a. Before **b. After** **c. Citarum River cleaning by the local community**



Source: Citarum River Basin authorities (2024).

Long-term planning and continuous monitoring are vital to track progress and to address emerging challenges. As Indonesia has shown, incorporating these lessons into future environmental conservation efforts can contribute to restoring and preserving natural resources globally.

STATE-OF-THE-ART TECHNOLOGY IN PEAT WATER TREATMENT: LESSONS FROM DUMAI, INDONESIA

Another case of river and lake restoration in Indonesia involves peat water, which is used for drinking after treatment in several countries in Southeast Asia. Dumai, in Riau Province on the eastern coast of Sumatra, relies on peat water that cannot be treated with a conventional treatment process. Through the National Urban Water Supply Project (NUWSP), a new treatment plant is treating peat water using a novel technology: hollow fiber nanofiltration (HFNF). This process can produce 50 liters per second of clean water.

Before the project started, the city-owned water utility in Dumai (Perumda Air Minum Tirta Dumai Berseri) faced managerial, technical, and financial challenges. Prior to the establishment of the HFNF treatment plant, the utility struggled to deliver clean water to its customers. As a result, customers depended on shallow wells of subpar quality for their daily water needs. They had to purchase drinking water from vendors at 50,000 to 80,000 Indonesian rupiah (IDR) ($3 to $5) per cubic meter. But water was not always available, especially during droughts. Many customers refused to pay their utility bill and refused to remain connected to the utility's network.

NUWSP's support in building the HFNF treatment plant helped the utility significantly improve water quality (Figure S.8) and lower monthly water bills. The treatment plant is now fully operational and provides services to new and existing customers. The increased number of customers and improved services have increased revenue and significantly improved the utility's performance.

FIGURE S.8 Dumai HFNF treatment plant

a. Treatment plant built under NUWSP

b. Untreated peat water (right) and treated water (left)

Source: PDAM Tirta Dumai Bersemai, Bukit Timah District (2024).

EQUITABLE AND INCLUSIVE ACCESS TO WATER SERVICES

ROLE OF TRADITIONAL KNOWLEDGE IN WATER MANAGEMENT: ENFORCEMENT OF EXISTING WATER CONTROL POLICIES, REGULATION OF WATER USE IN THE TOURISM SECTOR, AND PROTECTION AND PRESERVATION THROUGH THE SUBAK SYSTEM

Bali, Indonesia's renowned island destination, offers a compelling exploration of the nation's water crisis and local initiatives aimed at fostering equitable and inclusive water services.[5] Bali's water crisis primarily stems from the development of tourism, population growth, and inadequate water management. The island's groundwater availability has declined significantly due to these factors (USAID-SWP 2021). The situation deteriorated amid unregulated use of water resources, particularly in the tourism sector, which accounts for some 65 percent of Bali's total water consumption (Nastiti et al 2022).

Addressing the water crisis in Bali compels strict enforcement of existing water control policies, regulation of water use in the tourism sector, and preservation of traditional water management systems like the Subak, which governs the irrigation of Bali's rice terraces (GWP TAC 2000). The Subak system exemplifies the principle of inclusion through equitable allocation of water resources among rice farmers within a particular area. The Subak organization, a coalition of local farmers, oversees decisions regarding irrigation schedules, water distribution, and the maintenance of irrigation infrastructure. Governed by the concept of Tri Hita Karana, the system prioritizes the harmonious coexistence of humans, nature, and the spiritual realm (Provincial Government of Bali 2019, 2020). This philosophy recognizes the interconnectedness of these elements and strives to maintain balance among them. The Subak system is deeply rooted in Balinese spirituality, incorporating rituals and ceremonies that honor water deities and foster a harmonious connection between humans and the spiritual realm. The system ensures the responsible use of water resources and promotes sustainable agricultural practices (Risna et al 2022).

In recent years, Bali has committed to establishing sustainable water management practices, with the government acknowledging the significance of preserving the Subak system and fostering sustainable water management. Regulatory measures have been implemented to safeguard water resources—rivers, lakes, and waterfalls—and to ensure their sustainable use (Suyarto and Kusmawati 2016). Securing a sustainable future for Bali's water resources necessitates the embrace of sustainable water management practices, heightened public awareness, and the fusion of cultural wisdom with modern strategies. Through these measures, Bali can work toward alleviating the water crisis and ensuring the preservation of its crucial water sources for the well-being of future generations (Tataruangadmin 2019).

In today's era of relentless technological advancement in the digital sphere, it's tempting to believe that solutions lie solely in external technological innovations. However, as demonstrated by Bali's Subak system, traditional wisdom holds significant potential in addressing water crises (Hidayati 2016). Indeed, technological solutions for water challenges can synergize effectively with traditional knowledge and local practices (World Bank 2016).

COMMUNITY-BASED MANAGEMENT OF RURAL WATER SUPPLY: PAMSIMAS

The Community-Based Water Supply Program (PAMSIMAS) is a national program managed by MPWH since 2008. The objective of PAMSIMAS is to increase the number of underserved rural and peri-urban populations accessing sustainable water supply services. This objective aligns with the Government of Indonesia's dedication to attaining universal access to water supply, as outlined in its national mid-term and long-term development plans, as well as in Sustainable Development Goal 6 (United Nations 2023).

PAMSIMAS adopts a community-driven development approach, empowering communities to actively participate in the planning and management of water, sanitation, and hygiene within their villages. This approach fosters community ownership, enhances the involvement of women and other marginalized groups, and holds promise for long-term sustainability. PAMSIMAS (1) trains community facilitators in behavior change and the preparation of community action plans (CAPs) for water and sanitation, (2) provides incentive grants and technical support in the implementation of CAPs to offer services and increase coverage, and (3) operates a robust monitoring and evaluation system to collect information on the progress of activities and the functionality of facilities built under the program.

PAMSIMAS provides grants to finance community water improvement programs reflecting environmentally friendly technical options that are incorporated in CAPs with support from community facilitators. Communities that receive the grants then cover at least 20 percent of program costs, ensuring a sense of community ownership.

PAMSIMAS also supports the communities in establishing functional community-based institutions (Kelompok Pengelola Sarana Prasarana Air Minum dan Sanitasi) to effectively manage and finance systems and facilities. Between its inception in 2008 and the end of 2023, PAMSIMAS provided more than 24 million people with access to improved water facilities in more than 35,000 villages, 408 districts, and 33 provinces. In 2024, PAMSIMAS will provide support to 1,183 villages (Figure S.9).

PAMSIMAS is an important program for the Government of Indonesia for many reasons:

- It reaches rural and peri-urban communities without access to utility-supplied water.
- It supports behavioral changes, such as stopping open defecation and adopting handwashing with soap.
- Its community-driven development approach teaches the community how to plan, build, and operate water service systems.
- It enhances a sense of community ownership of program infrastructure and activities.
- Its targeted grants support the provision of drinking water to low-income communities at affordable rates.
- It encourages collaboration with the Baznas Fund, which supports the improvement of water supply services, and with various other funding sources such as micro creditors and the private sector.[6]

FIGURE S.9 PAMSIMAS beneficiaries

a. Sepa Village, Seram Island, Maluku Province

b. Larike Village, Ambon Island, Maluku Province

Source: MPWH Indonesia (2024).

COMMUNITY-BASED PROVISION OF SAFE DRINKING WATER: COASTAL AREAS AND SMALL ISLANDS

According to Indonesia's Ministry of Maritime Affairs and Fisheries, there are 17,520 small islands in Indonesia. Nearly all of them lack a basic feature: adequate drinking water. Tiny islands, which constitute approximately 28 percent of all Indonesia's islands, have minimal or no freshwater at all. They rely solely on rainwater.

Indonesia's Meteorology and Geophysics Agency has predicted that freshwater availability in the northern part of Sumatra Island and on the islands of Java, Bali, Nusa Tenggara, and Maluku, where water is already alarmingly low, will decrease even further between 2020 and 2034. To make matters worse, from 2031 to 2045, rainfall, which contributes to water availability and provides drinking water, especially for coastal communities and small and tiny islands, is expected to decline.

To address the challenges of the coastal and small island communities, the Indonesian National Research and Innovation Agency has developed a water treatment technology package. This package, which employs reverse osmosis technology, can treat brackish water or seawater with a total dissolved solids (TDS) concentration of 20,000–40,000 parts per million. With a processing capacity of 5,000 to 10,000 liters per day, the equipment unit includes raw saltwater extraction, initial processing, seawater reverse osmosis (SWRO) membrane filtration, and final or advanced processing. The water treatment equipment (a cupboard for filling gallon bottles and a generator for electricity) is encased in a protective building made of iron coated with anti-rust paint, facilitating installation in remote locations.

Since 2021, 24 units have been installed in coastal areas and small islands in South Sulawesi Province, contributing to ongoing efforts to provide safe drinking water in these vulnerable regions (Figure S.10). The units are managed by the community—specifically, the village cooperatives or village-owned enterprises (BUMDES). Processed ready-to-drink water is marketed in 20-liter refillable

FIGURE S.10 SWRO water treatment plant

Source: BUMDES (2024).
Note: This SWRO ready-to-drink water processing unit in Bontojai Village, Bantaeng, South Sulawesi, has a capacity of 10,000 liters per day.

bottles. The estimated production cost of approximately IDR 2,500 ($0.15) per bottle reflects fuel costs and bottle caps. Ready-to-drink water is sold for IDR 7,000 ($0.43) per 20-liter bottle, yielding revenue of IDR 4,500 ($0.28) per bottle. With the potential to sell 100 bottles of produced water daily, the revenue margin amounts to IDR 450,000 ($27.7) per day. Revenue is allocated for operational and maintenance costs, ensuring sustainable equipment operation.

INCENTIVE-BASED INVESTMENTS IN UTILITY PERFORMANCE: LESSONS FROM SEMARANG, INDONESIA

Semarang is located on the northern coast of Central Java. As the capital of Central Java Province, the city serves as the development center for the densely populated region. Clean water for the city is supplied by a municipally owned local water company (Perumda Air Minum Tirta Moedal). The company uses surface water as its main source. It treats and distributes clean water but supplies only half of the city population; the remaining population relies on dug or tube wells for water supply. The utility is struggling with high nonrevenue water (NRW) at around 39 percent (2019). Pipes that are more than 30 years old are among the causes of high NRW. Financing, which is needed to manage climate change, water resources, and water services delivery, is critical in addressing this problem.

In 2018, through NUWSP, the Government of Indonesia initiated a national framework for urban water supply development (NUWAS Framework). The NUWAS Framework introduced an incentive-based structure to provide tailored support to local governments and water utilities to improve their performance gradually but continuously and to leverage non-public financing. In the same year, to expand service, Perumda Air Minum Tirta Moedal signed a public-private partnership (PPP) agreement with PT Moya Indonesia to develop a water supply system (water treatment plant and main distribution network) in the western part of the city, with an investment of IDR417 billion ($30 million). Financial closure was reached on May 22, 2019, making the utility eligible to receive a matching grant from NUWSP as an incentive for its success in accessing non-public funding from a PPP scheme. The utility used the grant to finance rehabilitation or replacement of 28 kilometers of pipe in 13 service areas, with investment costs of IDR63 billion ($4 million).

In 2021, Tirta Moedal established a business-to-business contract with PT Tirta Nusantara Sukses to increase the capacity of the Gajah Mungkur Water Treatment Plant from 500 liters per second to 600 liters per second, allowing it to receive a second matching grant from the NUWSP in the amount of IDR 6.5 billion ($0.4 million). It used the fund to finance construction that doubled the capacity of a 1,000 cubic meter reservoir. As part of its commitment, Tirta Moedal contributed IDR 78 billion ($5 million) from its own funding to complete the work, which occurred from 2021 to 2023.

Enhanced production capacity, facilitated by the utility's collaboration with the private sector, and refinement of its distribution system empowered Tirta Moedal to extend its service reach and enhance its service reliability. The utility increased its operational hours from a mere 12 hours per day to 24 hours per day and allowed customers' monthly consumption to rise to 25 cubic meters. By the end of February 2024, nearly 20,000 additional household connections had been established, benefiting more than 65,000 individuals. Furthermore, more than 28,000 existing customers now enjoy improved and more dependable services.

Before the aforementioned projects were implemented, access to piped water in Semarang was restricted. Many consumers received service for less than 12 hours per day. Others faced long waits or resorted to purchasing refilled water from vendors or housing developers—water of questionable quality. Access to Tirta Moedal's piped water service has remarkedly improved the situation by providing a round-the-clock supply of high-quality water.

The incentive-based approach of the NUWAS Framework that has been applied in NUWSP has leveraged non-public financing to support urban water supply development. Another 16 water utilities have managed to access non-public financing through contracts with the private sector or domestic borrowing, leveraging a total of more than $150 million. NUWSP shows that a properly implemented incentive-based approach is effective in leveraging non-public funding sources to accelerate access to safe water through piped systems in urban areas.

The above-noted cases illustrate that investments, incentives, institutions, and inclusion must work in tandem. Investments in water-treatment technology by Indonesia's National Research and Innovation Agency and the National Urban Water Supply Project, as well as incentives for partnerships and performance, resulted in financial and well-being benefits. These benefits can drive human development, fostering healthy and productive individuals who, in turn, contribute to the economy through labor participation. Moreover, the benefits minimize healthcare costs, alleviating the burden on the healthcare system. Community participation, whereby village cooperatives or village-owned enterprises manage infrastructure and activities, helps make new, improved, and expanded water services sustainable. The result is that even the poorest and most vulnerable get access to safe water.

BOX S.1 Bundling investments in upstream and downstream activities to expand the water supply system in jakarta

Approximately 66 percent of the population in the Jakarta Special Capital Region (Daerah Khusus Ibukota or DKI Jakarta) have access to piped water supply services. These services are provided by water treatment plants that are already operating at full capacity. Expansion of the piped water supply system to achieve 100 percent service coverage is hindered by Jakarta's lack of water sources. In addition, aging distribution

Box continues next page

Box S.1 *continued*

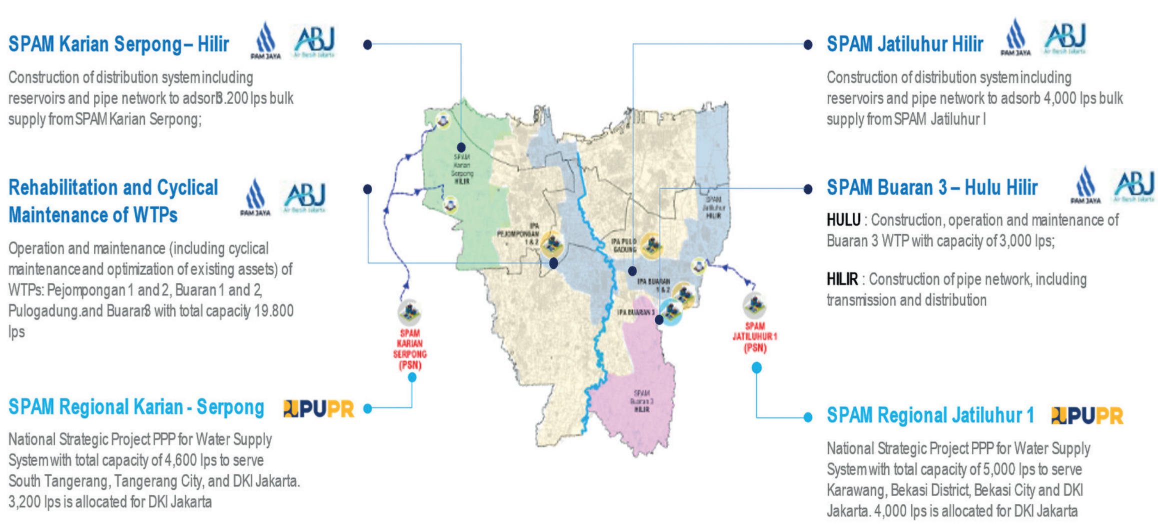
pipes are leading to water losses, and customers in areas far from distribution centers are experiencing intermittent supply. As a result, more than 35 percent of the population and the majority of high-rise and mixed-use buildings still rely on groundwater extraction to fulfill daily needs. This extraction is leading to land subsidence at a rate of 3–10 centimeters per year and is increasing Jakarta's flood risks. To stop groundwater exploitation, Jakarta needs to increase its water supply capacity by developing new water sources and production units and by improving the operational efficiency of its existing water supply infrastructure.

To improve Jakarta's water security, the Ministry of Public Works and Housing (MPWH), the Ministry of Home Affairs, and the DKI Jakarta Provincial Government are working together to develop an integrated water supply system (Sistem Penyediaan Air Minum or SPAM) encompassing both upstream and downstream initiatives for DKI Jakarta (Figure BS.1).

On the upstream side, to increase water production capacity, the central government, through the MPWH, will undertake construction of two regional integrated water supply systems (regional SPAMs): Regional SPAM Jatiluhur 1, with a capacity of 4,750 liters per second, and Karian Serpong, with a capacity of 4,600 liters per second. Both regional SPAMs are national strategic projects (Proyek Strategis Nasional or PSN) intended to increase water supply capacity for the Greater Jakarta region. In addition, the DKI Jakarta Provincial Government, through its provincial water enterprise PAM JAYA (Perusahaan Air Minum Jakarta Raya), will construct SPAM Buaran 3, with a capacity of 3,000 liters per second.

On the downstream side, PAM JAYA will improve the operational efficiency of existing infrastructure, expand distribution networks, and install new house connections. This concerted effort aims to provide piped drinking water access to all DKI Jakarta.

FIGURE BS.1 Components of SPAM DKI Jakarta (projects and implementing partners)



Source: Drinking Water Supply System (SPAM) Ir H Djuanda/ Jatiluhur MMPV Consortium and DKI Jakarta Regional Mid-Term Development Plan (RPJMD), 2022.

Box continues next page

Box S.1 *continued*

Significant amounts of investment are needed to build the infrastructure for upstream activities and to implement downstream activities. Both MPWH and Jakarta Provincial Government (DKI) have limited public funding. To support the government in project financing and to access expertise in improving operational efficiency, PAM JAYA invited the private sector to invest in the project using a bundling scheme that closely links investment in upstream activities with investment in downstream activities.

Under this bundling scheme, two financing streams are applied: new asset ("greenfield") financing and existing asset ("brownfield") financing. The greenfield projects are Jatiluhur Hilir (off-take facilities from SPAM Jatiluhur 1), Karian Serpong Hilir (off-take facilities from SPAM Karian Serpong), SPAM Buaran 3 Hulu (a new water treatment plant), and SPAM Buaran 3 Hilir (a new piped network that distributes water from the Buaran 3 Water Treatment Plant). The Brownfield projects involve optimization and rehabilitation of existing water treatment plants (cyclical maintenance).

The financing scheme for the greenfield projects is executed through an installment payment contract (Kontrak Berbasis Angsuran); brownfield projects will be financed from water charges per cubic meter of bulk water produced. Following a bidding process, on October 14, 2022, the "SPAM Cooperation Agreement through Optimizing Existing Assets and Providing New Assets with a Bundling Financing Scheme" was signed between PAM JAYA and PT Moya Indonesia. PT Air Bersih Jakarta (ABJ) was established to implement project activities.

Two greenfield projects, Jatiluhur Hilir and Karian Serpong Hilir, are connected to two regional SPAMs, Jatiluhur 1 and Karian Serpong. The MPWH implemented both regional SPAMs as PPP schemes that include construction of new water treatment plants (WTPs) and transmission pipes to supply bulk water for the Greater Jakarta region. PT ABJ will be responsible for construction of the distribution system, which includes reservoirs and a pipe network, to adsorb bulk water supply from Jatiluhur 1 and Karian Serpong and to distribute it to DKI Jakarta. PT ABJ will also be responsible for the construction, operation, and maintenance of the Buaran 3 WTP and distribution system, as well as for the optimization, rehabilitation, and operation of the existing WTPs in DKI Jakarta (Pejompongan 1 and 2, Buaran 1 and 2, and Pulogadung WTP, with a total capacity of 16,800 liters per second). Once Buaran 3 goes online, PT ABJ will be operating and maintaining WTPs with a total production capacity of 19,800 liters per second. To achieve 100 percent coverage by 2030, PT ABJ will install a 7,156-kilometer distribution network and more than 1 million house connections. The estimated capital expenditure for this project is IDR 23.92 trillion ($1.48 billion).

Note: This content was contributed by President Director Bano Rangkuty, PT Air Bersih Jakarta.

NOTES

1 This section reflects contributions from the Directorate of Dams and Lakes, Ministry of Public Works and Housing, Indonesia.

2 This section reflects contributions from Siswanto, Alberth Nahas, Marjuki, and Urip Haryoko, Meteorological, Climatological, and Geophysical Agency, Indonesia.

3 Presidential Regulation No. 60 of 2021 identifies these 15 national priority lakes: Lake Toba in North Sumatra Province, Lake Singkarak in West Sumatra Province, Lake Maninjau in West Sumatra Province, Lake Kerinci in Jambi Province, Rawa Danau Lake in Banten Province, Rawa Pening Lake in Central Java Province, Lake Batur in Bali Province, Lake Tondano in North Sulawesi Province, Mahakam Cascade Lakes (Melintang, Semayang, and Jempang) in East Kalimantan Province, Sentarum Lake in West Kalimantan Province, Limboto Lake in Gorontalo Province, Poso Lake in Central Sulawesi Province, Tempe Lake in South Sulawesi Province, Lake Matano in South Sulawesi Province, and Lake Sentani in Papua Province.

4 This section reflects contributions from the Coordinating Ministry of Maritime Affairs and Investment of Indonesia, River Basin Organization for Citarum (MPWH of Indonesia).

5 This section reflects contributions from Firdaus Ali, Indonesia Water Institute. Information comes from USAID SWP (2021), GWP TAC (2000), Hidayati (2016), Nastiti et al. (2022), Provincial Government of Bali (2019, 2020), Risna et al. (2022), Suyarto and Kusmawati (2016), and Tataruangadmin (2019).

6 The National Board of Zakat for the Republic of Indonesia (BANZAS) is an Indonesian government agency responsible for social funds.

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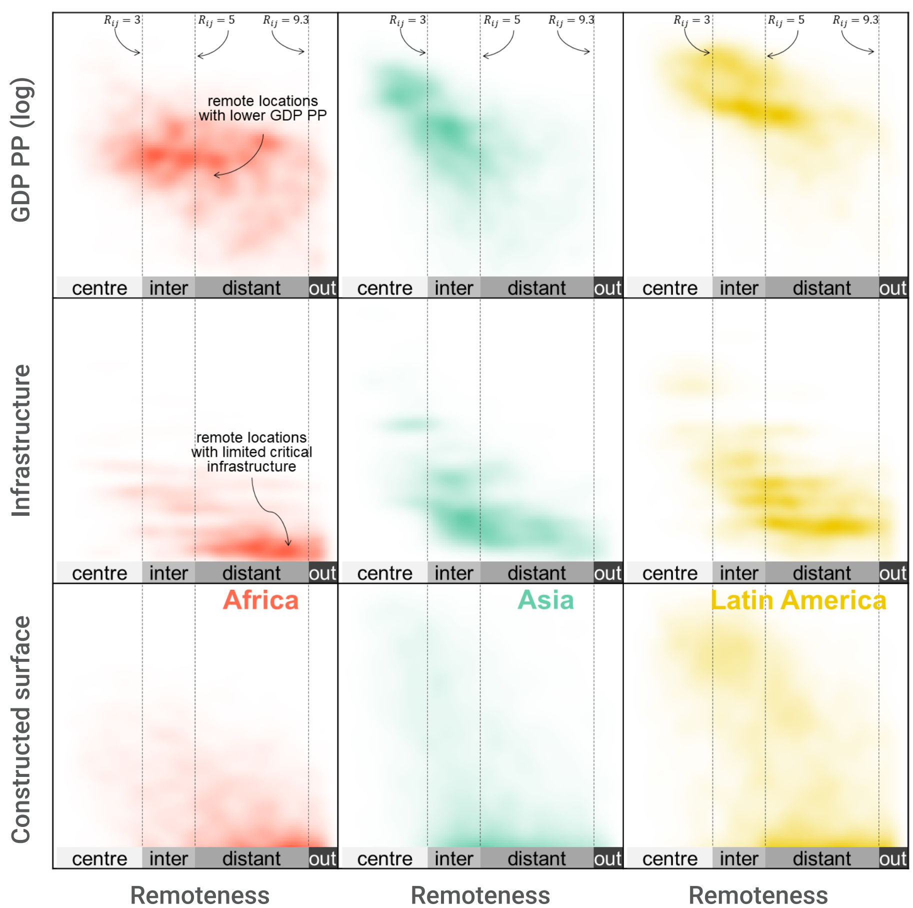
APPENDIX A
URBAN FORM AND WATER SERVICE PROVISION

Figure A1.1 illustrates the effect of urban form on water service provision in 106 cities across Africa, Asia, and Latin America. It reflects analysis of data on proximity to critical infrastructure and, at the city level, water tariffs and population with access to piped water. Remoteness of location is defined as the relative distance between one area and the city center. Remoteness is a comparable metric for distances between cities. Locations are classified according to remoteness: (a) the central area of the city, (b) the intermediate area, (c) the distant areas, and (d) the outmost areas.

FIGURE A1.1 Effect of urban form on water service provision in 106 cities across Africa, Asia, and Latin America



Note: World Bank.
Note: The figure reflects 7,300 pixels in Africa, 6,600 in Asia, and 5,800 in Latin America for which remoteness, defined as the relative distance from one location to the center of the city (horizontal axis), is compared with income (vertical axis), proximity to critical infrastructure, and the constructed surface within walking distance.

Compared with the central area of the city, the intermediate area has half the gross domestic product (GDP) per person and 30 percent less critical infrastructure. Compared with the central area of the city, the outmost area has one-eighth of the GDP per person and 70 percent less critical infrastructure (Table A1.1).

For a city, sparseness is measured as the average remoteness weighted by the population. In cities with more sparseness, the cost people pay for one cubic meter of water tends to be much higher. Water tariffs are, on average, 75 percent higher in a city with twice the sparseness.

When infrastructure at the city level is aggregated, analysis shows that people in sparse cities are, on average, far from infrastructure. On average, people living in a city with twice the sparseness have nearly 40 percent less proximity to critical infrastructure, thus reducing the probability of being connected to piped water. The population with access to piped water is estimated using national data from the Joint Monitoring Programme for Water Supply, Sanitation, and Hygiene (JMP). Results show that a city with twice the sparseness provides access to piped water to less than half of the population.

The pattern of urban form varies across regions. In cities in Asia, 54 percent of the population lives in the central or intermediate area. In Latin America, only 43 percent of the population lives in the central or intermediate area, and in Africa, only 28 percent of the population. In Africa, nearly 40 percent of the population lives in the outmost areas, thus having less proximity to infrastructure and increasing water tariffs (Table A1.2).

TABLE A1.1 Areas further away from city center are poorer and have less access to critical infrastructure

Area	GDP per person	Critical infrastructure	Building size (m^2)	# Buildings	Constructed surface (%)
Center	100	100	112	2,190	26
Inter	49	70	100	1,684	19
Distant	23	49	104	1,123	12
Outmost	12	30	94	682	6

Source: World Bank.
Note: GDP per person is based on purchasing power parity. Critical infrastructure in inter, distant, and outmost areas is compared with that in the city center. Average building size in square meters, number of buildings, and constructed surface (in percent) within walking distance are shown for different areas of a city.

TABLE A1.2 Distribution of the population in Africa, Asia, and Latin America according to the area of the city

Area	Africa	Asia	Latin Am.
Center	12%	23%	18%
Inter	16%	31%	25%
Distant	34%	37%	40%
Outmost	38%	9%	17%

Source: World Bank.

APPENDIX B ESTIMATING THE IMPACTS OF DROUGHTS AND FLOODS

Effects on the Human Development Index

The study examines the effects of droughts on the Human Development Index (HDI). The analytical framework combines disaggregated data on grid-level HDI with geospatial information on weather conditions to construct the Standardized Precipitation Evapotranspiration Index (SPEI) as a measure of droughts. Available panel data for the 2005–15 period allowed for a difference-in-differences approach that concentrates on droughts as a critical impact on human development.

A categorical variable is defined based on the intensity (cumulative duration) of abnormal rainfall conditions within a year. An SPEI less than -1 was considered abnormal. Drought categories were established as moderate (1–3 months), high (4–6 months), and severe (7+ months). These categories served as exogenous treatment shocks in a difference-in-differences econometric model. The model was specified as:

$$y_{ict} = \alpha + \gamma_t + \sum_{j=1}^{3} \delta_j * intensity_{jict} + \sum_{j=1}^{3} \sum_{t=1}^{T} \varphi_{jt} * (intensity_{jict} * t) + \varepsilon_{ict}$$

Where y_{ict} is the variable of interest (HDI) for raster i of country c during year t; α is a vector of fixed-effect coefficients: one with raster-level fixed effects (for which it would take the notation α_i), and another with country-level fixed effects (α_c); γ_t is a time fixed-effect that keeps track of the global overall trend of HDI growth; $intensity_{jict}$ is the previously defined categorical variable of rainfall events intensity, where δ_j are the parameters that measure the selection effect of the countries affected by different intensity (j) of rainfall events. φ_{jt} consist of parameters of interest that explain the effect of rainfall event intensity after some number of periods and are akin to the treatment effect of the exogenous shock of the rainfall events.

The estimates of the effect of different rainfall events included the parameters of intensity (φ_{jt}) throughout the 2006–15 period, using the year 2005 as a reference point. The trends indicate that increased rainfall event intensity has a negative effect on HDI. Moderate-intensity events exhibit a gradual decline in HDI, with a slight improvement toward the end of the observed period. High-intensity events show a more pronounced negative impact on HDI, with the steepest decline around 2015. Extreme-intensity events demonstrate the most significant initial decline in HDI, suggesting that the higher the number of months with abnormal rainfall, the more adversely affected HDI is.

Effects on education and income

The estimation procedure unfolds as follows: First, learning-adjusted years of schooling (LAYS) are calculated using the methodology outlined by Filmer et al. (2020). LAYS serves as the baseline scenario, incorporating the existing loss of learning attributable to observed weather shocks. Next, a counterfactual scenario for LAYS is estimated, assuming no precipitation shocks occurred. In other words, this scenario considers higher Harmonized Learning Outcomes (HLO) scores resulting from reduced performance effects caused by the absence of these shocks. A lower-bound estimate of the effects is established to quantify the gap between the baseline and counterfactual scenarios. This estimate assumes that one month of shock is equivalent to a loss of 20 days of schooling. This figure aligns with similar measures of schooling effects resulting from weather shocks. However, this lower bound does not account for potential long-lasting effects on learning performance due to factors such as catastrophic consequences of natural disasters, enduring illnesses stemming from the shocks, or the loss of access to essential water services.

Lost days of schooling are subsequently translated into HLO points using the method outlined by Azevedo et al. (2020). This conversion assumes that a full school year is equivalent to a range of 40 to 60 points, depending on a country's income level. The resulting HLO score is then employed to compute the counterfactual LAYS. Formally, the HLO loss is defined as:

Where $yearly\_gains_i$ is Azevedo's gains in HLO by year of schooling of the average individual of country i, and $shock_i$ is the loss of schooling in years due to the shock as defined by:

$$HLO_i^{loss} = yearly\_gains_i * shock_i$$

Where $event\_duration$ is the average length in days of rainfall shocks to which the country's population is exposed, and $days\_schooling$ is the length of the school year in each country.

$$shock_i = \frac{event\_duration_i}{days\_schooling_i}$$

Then, HLO_i and HLO_i^{loss} are used to calculate the baseline and counterfactual LAYS as well as LAYS loss:

Using Azevedo et al.'s estimates for Mincerian returns to education, the analysis estimates the effects of such LAYS loss to income by defining returns loss and income loss as:

$$LAYS_i^{baseline} = EYS_i * \left(\frac{HLO_i}{625}\right)$$

$$LAYS_i^{counterfactual} = EYS_i * \left(\frac{HLO_i + HLO_i^{loss}}{625}\right)$$

$$LAYS_i^{loss} = LAYS_i^{counterfactual} - LAYS_i^{baseline}$$

Where r_i is the return of an additional year of education, and y_i is the average monthly labor earnings of individual i's country. This estimated loss is used to compute a net present value projection of

$$r_i^{loss} = r_i * LAYS_i^{loss}$$
$$y_i^{loss} = y_i * r_i^{loss}$$

lifetime earnings with and without loss, assuming a labor life of 40 years and a yearly discount rate of 4 percent:

$$Y_i^{baseline} = \sum_{t=0}^{39} \frac{y_i}{(1 + 0.04)^t}$$

$$Y_i^{counterfactual} = \sum_{t=0}^{39} \frac{y_i + y_i^{loss}}{(1 + 0.04)^t}$$

$$Y_i^{loss} = Y^{counterfactual} - Y_i^{baseline}$$

The economywide effect is calculated as the lifetime loss multiplied by the rainfall risk-exposed population of country *c* during the 21 years of the analysis:

$$Y_c = \sum_{y=2020}^{2020} y_i^{loss} * exposed\_pop_{cy}$$

Effects of COVID-19 versus effects of rainfall shocks

Table A2.1 compares the effects of COVID-19 and extreme rainfall shocks from 2000 to 2022. COVID-19 affected 628,891,265 school-age individuals. In contrast, flood shocks (SPEI >1) affected 250,000,000 school-age individuals, and extreme flood shocks (SPEI >2) affected 139,200,000 school-age individuals. The average duration of extreme rainfall shocks (1.18 months) was shorter than that of the COVID-19 crisis (5 months); nevertheless, the potential for more frequent and intense rainfall shocks due to climate change is troubling.

Economically, the immediate effect of COVID-19 was more severe than that of rainfall shocks, with an annual income loss of $872 PPP per individual. This figure is significantly higher than the losses from flood shocks and extreme flood shocks, which were $270.91 PPP and $211.86 PPP, respectively. The present value of lifetime income loss is also greater for COVID-19 than for rainfall shocks. That loss was $5,576 PPP for flood shocks and $4,361 PPP for extreme flood shocks—substantial but markedly lower than for COVID-19 at $15,901 PPP.

The loss as a proportion of baseline lifetime income is 1.54 percent for flood shocks and 1.30 percent for extreme flood shocks, which, although significant, is lower than 5 percent for COVID-19. The silent, cumulative effect of these flood events, particularly considering their increased frequency and intensity due to climate change, necessitates serious consideration of their long-term impact. Additionally, the economic impacts presented in Table A2.1 include both lower-bound and upper-bound estimates, highlighting the importance of comprehensive evaluations to fully understand the economic repercussions of these environmental shocks.

TABLE A2.1 Effects of COVID-19 versus effects of extreme rainfall shocks (2000–22)

	Flood shocks (SPEI>1) (2000–22)	Extreme Flood shocks (SPEI>2) (2000–22)	COVID shock (2020–21) (Azevedo et al. 2019)
Countries in sample	147	147	157
Exposed school-age population	250,000,000	139,200,000	628,891,265
Average shock duration (months)	2.15	1.83	5
HLO loss	8.86	7.43	16
LAYS loss	0.15	0.12	0.6
Yearly income loss ($ PPP)	270.91	211.86	872
PV lifetime income loss ($ PPP)	5,576.48	4,361.01	15,901
Loss as share of baseline lifetime income	1.54%	1.30%	5%
Economy-wide effect (millions of $ PPP)	1,295,000	565,100	10,000,000

Source: World Bank.
Note: HLO = Harmonized Learning Outcomes; LAYS = learning-adjusted years of schooling; PPP = purchasing power parity; PV = present value; SPEI = Standardized Precipitation Evapotranspiration Index.

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