Water Security and Climate Change

Insights from Country Climate and Development Reports

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KEY MESSAGES

- **Most critical climate change impact channels discussed in the Country Climate and Development Reports (CCDRs) are directly or indirectly related to water,** including water shocks affecting agricultural and energy production, water-related diseases impacting health and labor productivity, and water-related natural disasters and resulting infrastructure damages. While estimates of the impact differ across countries, the poor and vulnerable are often disproportionately affected.
- **Water sector actions can contribute to both climate mitigation and adaptation.** Approximately 10 percent of global greenhouse gas emissions are linked to water-related activities. The water sector offers significant untapped potential for climate mitigation and plays a crucial role in providing innovative solutions necessary for the transition to green energy. Investments in water adaptation deliver substantial social and economic benefits.
- **The investment requirements in the water sector are substantial, and the financing gap is equally significant.** The private sector needs to play a crucial role in bridging this investment gap. To encourage private participation, it is essential to establish clear and transparent governance and policies, implement blended financing mechanisms, and adopt pricing incentives that reward sustainable water investment and management.
- **Demand-side management often proves to be more cost-effective in addressing water supply shortages than investing in supply-side solutions.** Effective water demand management involves adjusting water tariffs to reflect the true value of water in water allocation and use, increasing consumer awareness, and strengthening regulations and technologies to improve water use efficiency. Increasing efficiency requires countries to overcome political-economy barriers while repurposing wasteful water subsidies. Countries experiencing water stress are more likely to recommend water tariff reforms in their CCDRs.
- **Future CCDRs can be further improved** by (1) systematically estimating the investment needs of the water sector and evaluating their cost-effectiveness, (2) improving modeling approaches to better assess the impact of water sector shocks on the macroeconomy, (3) developing a stronger narrative regarding the effects of water shocks on employment and the importance of transboundary water management, and (4) emphasizing the importance of monitoring the outcomes of water sector investments through systematic data collection, including the use of remote sensing technologies.

The key findings of this report are also highlighted in the 2024 World Bank CCDR summary report, "People in a Changing Climate: From Vulnerability to Action," available at https://www.worldbank.org/en/publication/country-climate-development-reports.

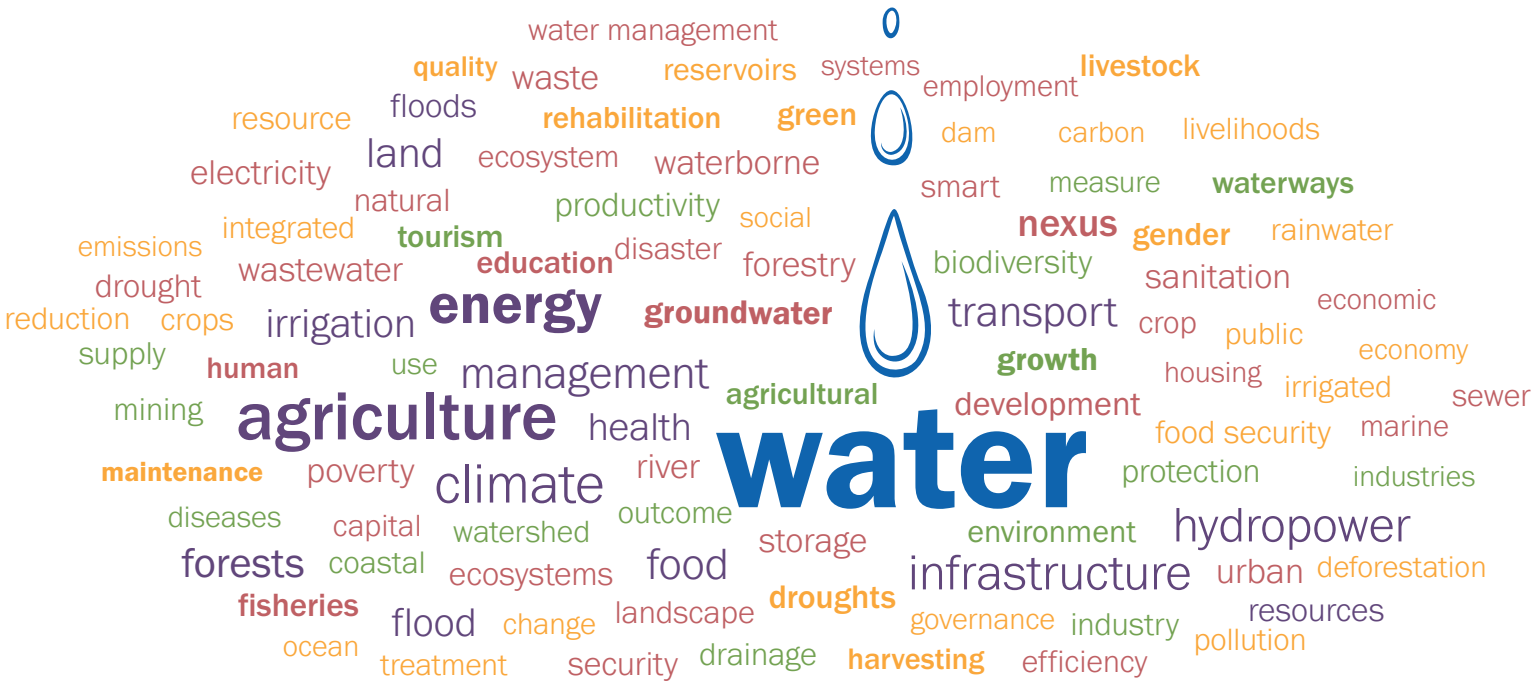
To support the alignment of development and climate objectives at the country level, the World Bank Group launched the Country Climate and Development Report (CCDR). CCDRs help governments, private sector investors, citizens, and development partners prioritize the actions that deliver development benefits, enhance resilience and adaptation, and reduce greenhouse gas (GHG) emissions.

Because water provides inputs to many economic sectors (agriculture, energy, transport, forests, and fisheries) and climate change manifests itself through changes in the water cycle, it is valuable to understand how CCDRs capture the water sector and to identify emerging insights on water sector actions in the context of climate change.

This report answers these crucial questions from the vantage point of CCDRs released in 2022, 2023, and 2024.[1] It examines a range of water-related climate risks and associated reforms as presented in these reports. A team of experts used climate change-related key words and text-mining techniques to review some 3,900 pages of CCDR text. Data visualizations of text mining results indicate the importance of the water sector for human capital, economy, and environment. Country-specific examples are mentioned for the countries where water was recognized as the most pertinent ingredient for socioeconomic development.

The CCDRs provide comprehensive coverage of water. Water-related challenges are the most frequently mentioned challenges in the CCDRs (figure 1). Almost all completed CCDRs highlight water-sector recommendations as key for adaptation, mitigation, or both. Thirty-nine countries conducted water sector-related deep dives or analyzed the water/climate change/development nexus (figure 2). The Water Global Practice co-led CCDRs for Angola, Iraq, Kenya, Malawi, and Zimbabwe.

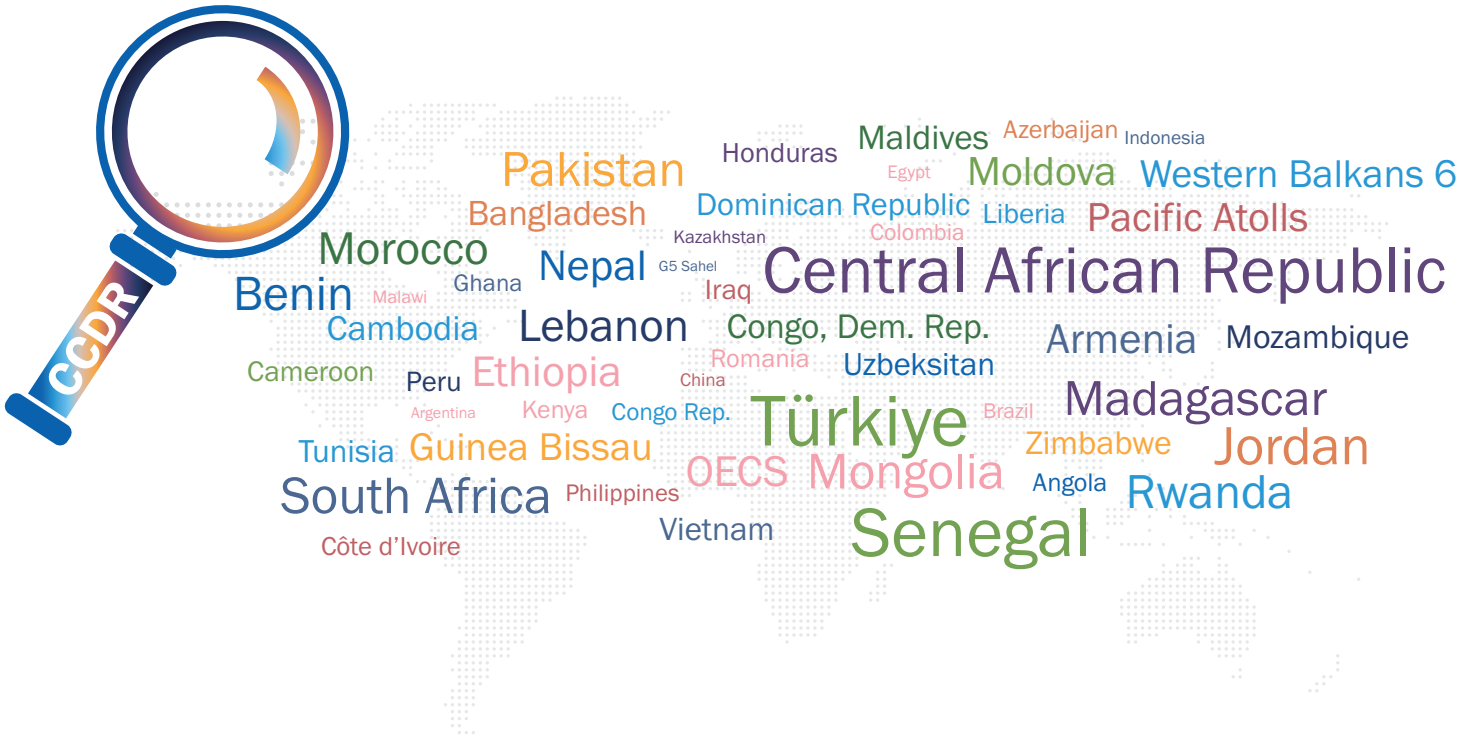
FIGURE 1 CCDRs Prepared Between 2022 and 2024 Extensively Cover Water



Source: Analysis is based on 52 completed CCDRs (25 in 2022, 16 in 2023, and 11 in 2024).
Note: The word cloud shows the most frequently used words in the CCDRs. Larger and bolder type indicates higher frequency.

CCDRs conclude that water plays a crucial role for agricultural productivity and food security, human development, economic growth and jobs, and the environment. Water sector actions are critical for reducing GHG emissions, adapting to climate change, and building resilience. Investing in a climate-resilient, water-secure future provides large economic and social returns. Improving water-related resilience is among the top five issues tackled by the CCDR recommendations, together with climate finance, decarbonizing power generation, increasing economywide resilience and adaptation (including the social aspects of both), and decarbonizing transport. Sustainable water management greatly enhances the synergy between resilience and development. Two central challenges to achieve sustainable water management are closing the financing gap and reforming institutions.

FIGURE 2 Water Through the CCDR Lens



Source: Analysis is based on 52 completed CCDRs (25 in 2022, 16 in 2023, and 11 in 2024).
Note: The word cloud shows the frequency of water-related discussions in a CCDR. Larger type represents higher frequency.

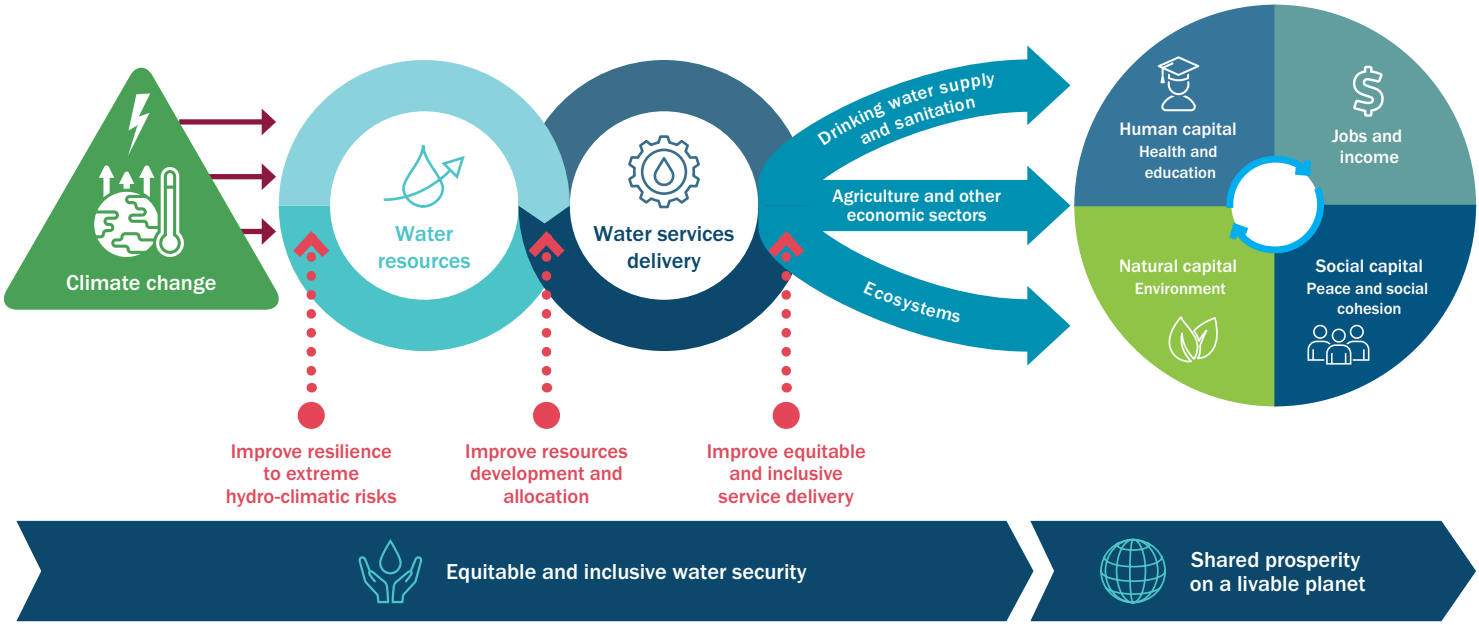
Context: Why water matters

The water sector is central in adapting to the changing climate because it intersects with numerous economic sectors, offering essential inputs for agriculture, energy, transportation, forests, and fisheries (figure 3). Water is the most frequently mentioned sector in the analyzed CCDRs. Changes in the water cycle due to climate change create uncertainty in the economy. When estimates and impacts of these changes differ widely, the uncertainty increases even more. For instance, by 2050, under a dry or hot scenario, the Sahel countries could experience between a 5 percent and a 10 percent fall in crop revenues and an 11 percent to 20 percent fall in livestock yield, whereas in a wet scenario, the impact on livestock yields could be positive in all countries (World Bank 2022a).

The water sector offers significant untapped potential for climate mitigation. Up to 10 percent of global GHG emissions are water-related (US Water Alliance 2022). These emissions include direct emissions of methane and nitrous oxide from irrigation, wetlands, and wastewater and indirect emissions through energy used in water supply and treatment.

More importantly, water is an essential element for building shared prosperity on a livable planet. There are 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 influences these four aspects of 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 3) (Zhang and Borja-Vega 2024).

FIGURE 3 Equitable and Inclusive Water Security for Shared Prosperity on a Livable Planet



Source: Zhang and Borja-Vega 2024.

Sustainable water management delivers both development and climate benefits. Improved water and sanitation infrastructure can reduce the spread of waterborne diseases, promote better health and education outcomes, and enable communities to better withstand the impact of droughts and floods. Nature-based solutions can boost carbon sequestration, replenish water resources, and benefit poor communities that disproportionately rely on water and nature for livelihoods. Climate-smart irrigation can significantly reduce methane emissions from agriculture and enhance agricultural productivity.

Between 2015 and 2022, the proportion of the world's population with access to safely managed drinking water increased from 69 percent to 73 percent. Nevertheless, countries face growing challenges linked to water scarcity, water pollution, and degraded water-related ecosystems. In 2022, some 2.2 billion people still lacked safely managed drinking water, 3.5 billion people lacked safely managed sanitation, and 2 billion lacked a basic handwashing facility

(United Nations 2023). Eighty percent of rainfed agriculture needs climate-smart agriculture practices to increase food production. With 4 billion people living in water-scarce areas and billions vulnerable to floods and droughts, there is an urgent need to improve sustainable water management as a critical strategy for addressing climate change mitigation, adaptation, and development.

Key water-related findings from CCDR reports

Climate change impacts on water resources and water services provision

Climate change is expected to lead to large changes in the water cycle, with consequences that could be large and uneven across the globe. Changes in temperature and precipitation due to climate change generate disruptions in the water cycle that increase the frequency and intensity of droughts and floods, impact water availability, and lead to sea level rise. All 52 analyzed CCDRs described how these changes adversely impact growth, prospects, and livelihoods. For example: water availability in Iraq could decline by 13 percent to 28 percent by 2050 due to climate change. For Central Asian countries, climate projections suggest that the flow of the Amu Darya River will decrease by 5 percent and the Syr Darya, by 15 percent by 2050; the frequency of low-water-flow and drought years will increase, and runoff losses are expected to be as much as 25 percent to 40 percent. The Caribbean Sea experienced an average change in sea level of 1.7 mm/y (+/- 1.3) over the 1993–2010 period. By 2050, coastal areas of the Dominican Republic are likely to experience an average sea level rise of +0.5 meters (RCP 8.5) and by 2069, an average rise of 0.6 meters (RCP 8.5). In Ethiopia, it is estimated that 5 million people are exposed to an average drought and 0.25 million people to an average flood event every year. With climate change, water supply will become more erratic, and water scarcity will greatly worsen in regions where water is already in short supply, such as in the Middle East and the Sahel in Africa (World Bank 2016). Unless investments are made to manage and mitigate this uncertainty, the impacts will be significant.

Most critical climate change impact channels discussed in the CCDRs are directly or indirectly related to water, including water shocks affecting agricultural and energy production, water-related diseases impacting health and labor productivity, and water-related natural disasters and resulting infrastructure damages. For example, by 2040, it is estimated that hydropower generation in Ghana could decline by 8 percent to 30 percent compared to 2020 levels. In Argentina, annual losses in rainfed agriculture from water deficits or excesses are estimated at $2.1 billion (0.6 percent of GDP). Drought in Cape Town led to a loss of 20,000 jobs in agriculture, resulted in a decrease in tourist numbers, and led to a direct economic impact of 3.4 percent of provincial GDP and 0.3 percent of national GDP in 2018. In Bangladesh, projected sea level rise could nearly double asset risk by 2050, while threatening agricultural production, water supply, and coastal ecosystems. In Egypt, under a medium sea level rise scenario (RCP4.5 SSP2), GDP losses of 1 percent annually could occur by 2030 and grow to about 3 percent in 2100. In Lebanon, climate change is projected to reduce water availability by up to 9 percent by 2040 (and up to 50 percent during the dry season) and to induce significant losses in agriculture (up to US$250 million per year) and tourism (due to a decrease in the number of snow days and a higher frequency of forest fires). In Uzbekistan, a rising incidence of waterborne and heat-related illnesses could result in a 0.6 percent to 1.2 percent increase in mortality by 2050. By the 2040s, waterborne diseases in Zimbabwe are projected to increase by 57 percent in a wet/warm scenario and 123 percent in a hot/dry scenario.

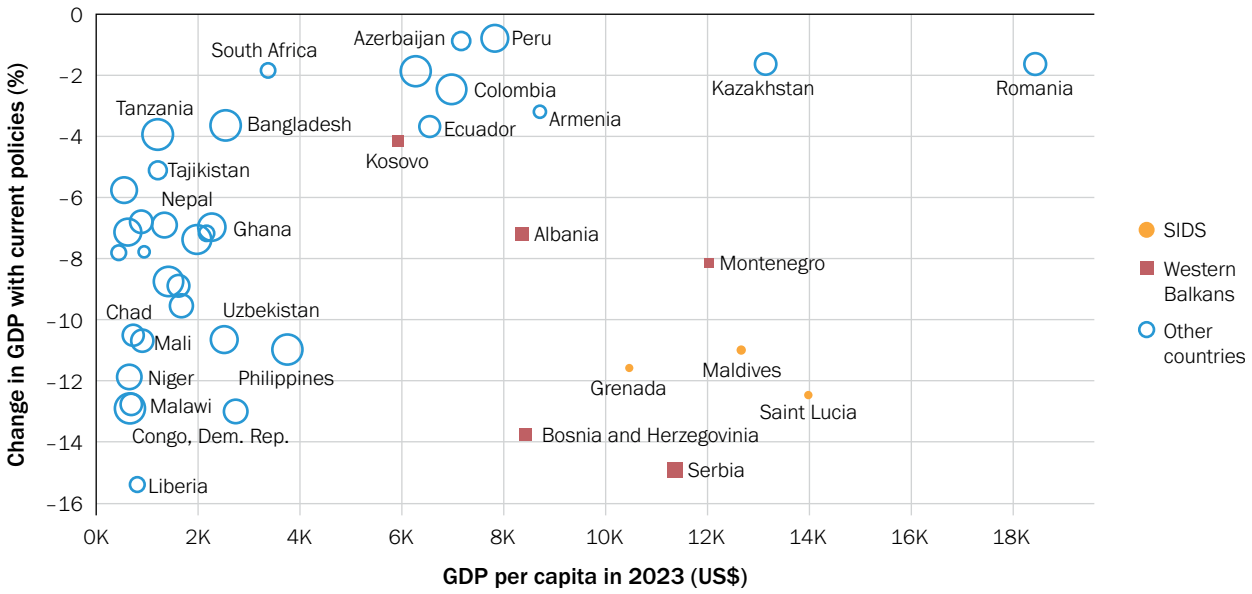
Climate change impacts on water availability have regional implications. Increasing demands on the world's shared water resources, coupled with increasing uncertainty due to climate change, could exacerbate regional tensions over transboundary water resources and increase the cost of adaptation measures as countries seek

sovereign solutions. However, cooperation is often the least-cost solution to securing water supplies, while also generating peace dividends and strengthening regional resilience. Although clear directions have been set for water resource management policy, further strengthening of governance and regional cooperation—on policy, institutions, and regulations—is required (World Bank 2022b).

Macroeconomic impacts of climate-induced changes in water availability and quality

Water availability is becoming less predictable in many places. In some regions, droughts are exacerbating water scarcity, threatening sustainable development and biodiversity worldwide.[2] Regions affected by water scarcity could see their growth rates decline substantially due to water-related impacts on agriculture, health, and incomes. Under the most pessimistic climate scenarios, Niger and some other countries may face a 12 percent decline in annual GDP compared to a medium-growth baseline (figure 4). Without reform, a 10 percent fall in water supply in Türkiye could reduce GDP by 6 percent. In a hot/dry climate scenario, up to 16.7 percent of the Dominican Republic's GDP could be lost relative to the baseline. Drought conditions in Malawi increase the probability of an individual falling below the poverty line by 14 percent. In the Sahel Region, without climate adaptation, by 2050, annual GDP compared to a medium-growth baseline would be reduced by between 6.8 percent (Burkina Faso) and 11.9 percent (Niger) under the dry and pessimistic climate scenarios. That decrease could be large enough to wipe out most or all of the annual growth in real GDP and real GDP per capita.[3] The impact will be more significant in places without sufficient water storage infrastructure and relatively reliant on rainfed agriculture. In that sense, climate change will exacerbate global inequality and the poor and vulnerable are often disproportionally affected.

FIGURE 4 Estimated Impacts of a Pessimistic Climate Scenario on GDP by 2050

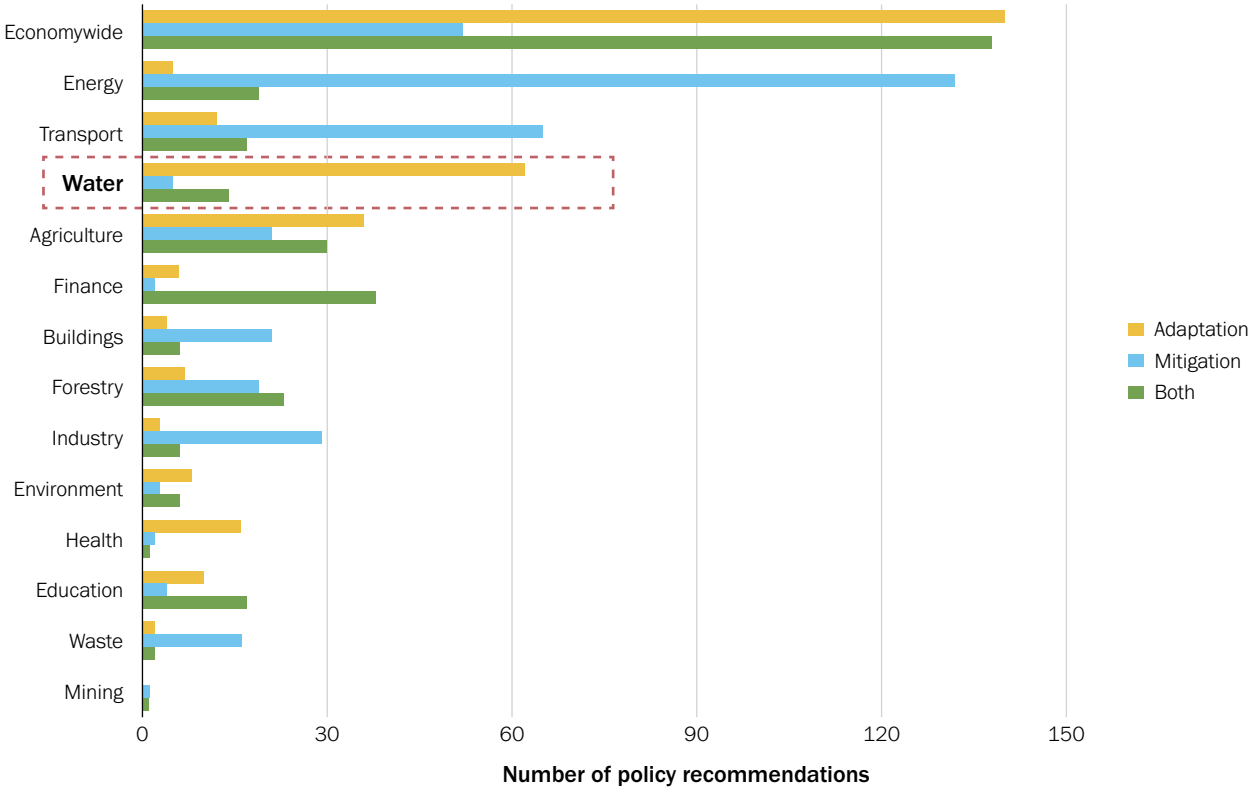


Source: World Bank 2023a.
Note: GDP = gross domestic product; SIDS = small island developing states.

Water sector contribution to climate mitigation and climate adaptation

Water sector actions can contribute to both climate adaptation and mitigation. CCDRs included water sector recommendations for both adaptation and mitigation actions. Water sector recommendations focus mostly on adaptation (figure 5).

FIGURE 5 Recommendations on Adaptation Versus Mitigation by Sector



Source: World Bank 2022c.

The water sector holds untapped potential for climate mitigation. About 10 percent of global GHG emissions are water-related, including direct emissions of methane and nitrous oxide from irrigation, wetlands, and wastewater and indirect emissions generated through the energy used in water supply and treatment. About 2 percent of GHG emissions come from water utilities, equivalent to those from the world's shipping industry. Fifty percent of the energy-related GHG emissions from the wastewater sector can be abated with existing technologies and at zero or negative cost.

The water-energy nexus becomes increasingly important in an era of climate change. Climate change impacts on water availability could impair energy sector decarbonization strategy. In Romania, for example, about 50 percent of the country's electricity generation comes from hydropower and nuclear. The Romania CCDR acknowledges the reliable supply of water resources as being critical to Romania's energy security and decarbonization (World Bank 2023b).

Water also underpins innovative solutions needed for the green energy transition. Many countries (Angola, Azerbaijan, Brazil, Colombia, Morocco, Nepal, Pakistan, Romania, and Türkiye, for example) have shown interest in becoming producers, users, or exporters of green hydrogen, which requires reliable access to water. Co-location of pumped hydro and reservoirs with renewable energy sources (in Angola and Jordan, for example) could support renewable energy integration. In Colombia, a significant increase of solar and wind power generation capacity, combined with high hydroelectricity use, represents the least-cost option to expand electricity generation.

Conversely, technologies to increase water supply are often energy-intensive. Countries such as the Arab Republic of Egypt and Morocco are actively investing in desalination and wastewater reuse plants to reap the benefits of expanded water supply, reduced methane emissions, and biogas generation (box 1). However, desalination and wastewater treatment are energy-intensive, and the choice of energy sources has significant implications for countries' decarbonization efforts.

Groundwater pumping affects GHG emissions, depending on the source of energy, and has water security implications. If pumps are running on fossil fuel, GHG emissions will increase. If pumps run on renewable energy such as solar energy, the marginal costs of pumping will decrease, creating a risk of over-exploitation of groundwater. Solar pumping in combination with net-metering could be a potential solution.

BOX 1 Desalination as a Viable Water Supply Option

Desalination can improve the reliable supply of fresh water and help reduce pressure on existing freshwater resources. Countries facing water shortages, such as Egypt, Iraq, Jordan, and Tunisia, are exploring a combination of groundwater pumping, water harvesting, and desalination to meet demand for water. In Egypt, an estimated 76 plants are in operation, with capacity expansion from 140,000 m^3/day in 2014 to 750,000 m^3/day in 2021. This fivefold increase will improve resilience of water supply for drinking, tourism, and industry in coastal areas. In Tunisia, a new public-private partnership (PPP) framework aims to help the private sector partner with the state to develop several desalination and wastewater treatment plants. The private sector investment potential in the water sector is estimated at between US$2.9 billion and US$3.4 billion, most of which will be used to develop desalination plants for the agriculture sector.

However, given the high energy intensity of the desalination process, the choice of energy sources must align with country's decarbonization targets. In Morocco, the Plan Nacional de l'Eau (National Water Plan) acknowledges that desalination of seawater is based on energy-intensive technologies. To meet Morocco's decarbonization targets, desalination plants will need to rely on energy from renewable sources, such as wind and solar power.

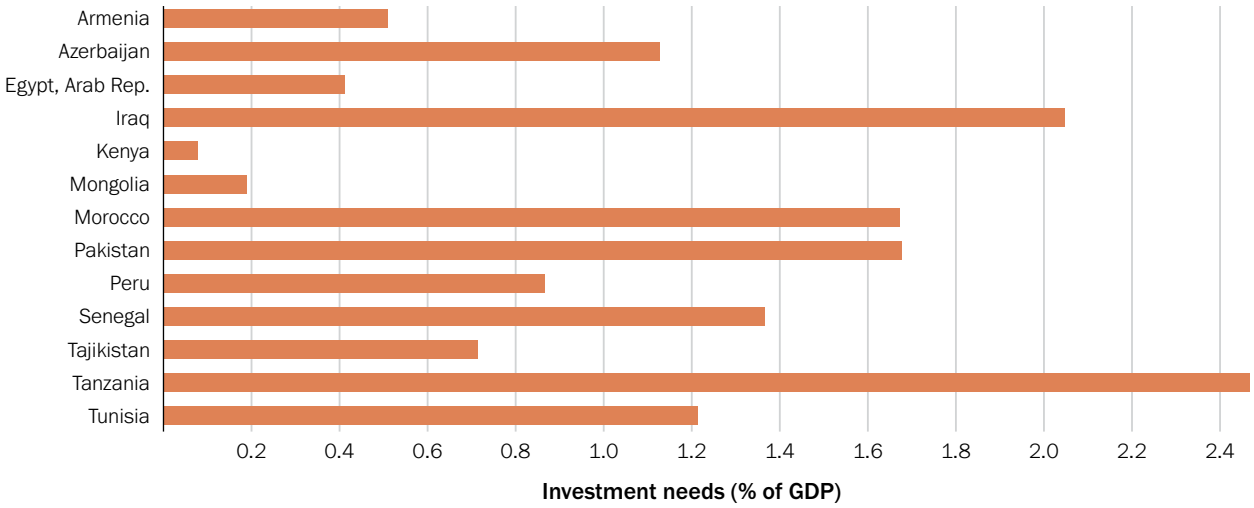
Source: World Bank Country Climate and Development Reports.

Water investments yield significant social, economic, and climate returns. The net benefits of investing $1.8 trillion globally in five areas related to adaptation in water are estimated at $7.1 trillion from 2020 to 2030 (Global Commission on Adaptation 2019).[4] In Peru, adaptation investments can increase GDP by 5 percent, mostly due to agriculture and water co-benefits. In Jordan, water and energy efficiency measures could significantly reduce water sector costs and achieve operational cost recovery by 2040. In Cambodia, increasing annual investment in water, sanitation, and hygiene by 5 percent could nearly offset negative climate change impacts on labor supply by 2050. In Morocco, investing in climate adaptation infrastructure for droughts could reduce GDP losses by almost 60 percent. In Pakistan, improving sanitation could reduce stunting among children under 5 from 40 percent to 30 percent by 2030—and to 5 percent by 2050—with a significant increase in labor supply.

Challenges in the water sector

The CCDRs identify overarching challenges common to many countries. First, the massive investment needs in the water sector also imply an equally large financing gap. The first group of completed CCDRs indicates annual water sector investment needs could range from less than 0.5 percent to nearly 3 percent of GDP per year for the next 10 years (figure 6).

FIGURE 6 Water Sector Investment Needs for a Resilient and Low-Carbon Pathway, 2022–2030



Source: World Bank 2022c.

Investment in the water sector is lower than in other sectors and is dominated by public spending. Ramping up adaptive investments (especially in the near term) may increase macroeconomic risks for many fiscally constrained countries. Annual spending on water in developing countries amounts to approximately US$164.6 billion, which represents only about 0.5 percent of GDP, lower than investments in other sectors such as health or education. The majority of this spending (91.4 percent) comes from the government and state-owned enterprises, with a strong emphasis on water supply and sanitation (76 percent of public spending). In contrast, the private sector contributes

a mere 1.7 percent of the total water sector spending, while Official Development Assistance (ODA) accounts for the remaining 6.9 percent (Joseph et al. 2024). Public and private investment is hindered by factors such as weak incentives for operational and financial efficiency, lack of supportive governance arrangements, high transaction costs, and the slow pace of sector reforms (Khemka, Lopez, and Jensen 2023). As the World Bank's new Private Capital Facilitation program stresses, there is a need to support an enabling environment in which governance, policies, institutions, and regulatory frameworks are clear, transparent, and implemented with integrity and in which firms have incentives to operate efficiently.

Second, demand-side management is often more cost-effective in reducing water supply shortages than supply-side investments but faces political barriers. Water demand management involves adjusting water tariffs to reflect the true value of water in overall water management (allocation and use), increasing consumer awareness, and strengthen regulations and technologies to improve water use efficiency. However, water is often underpriced, leading to wasteful consumption and significant fiscal costs. Subsidies in Pakistan's Punjab and Sindh provinces, for example, encourage lower-value production, unsustainable groundwater use, and continued GHG emissions. Indirect subsidies cost government up to $2.7 billion per year, with little benefit flowing to households or farmers and no incentive to increase productivity. However, pricing reform is politically sensitive due to affordability concerns and the perspective that access to water is a basic human right. The Pakistan CCDR highlights how the political economy of the sector locks farmers into a cycle of environmentally harmful, low-productivity, and low-income production (World Bank 2022d).

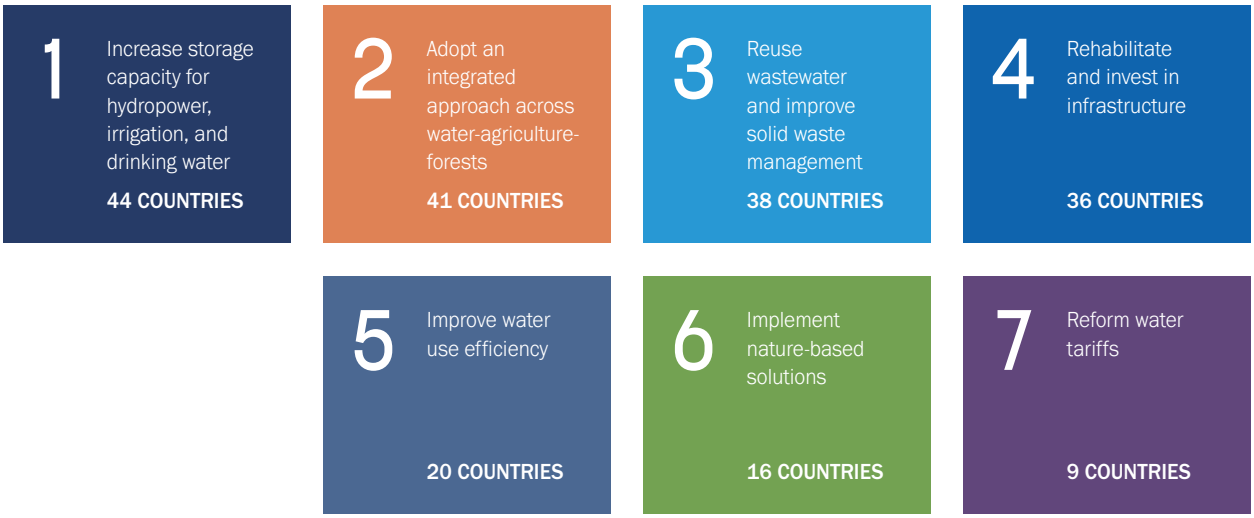
In addition, improved allocation of scarce water resources across different sectors is crucial for delivering both development and climate benefits. However, countries also face political economy barriers in achieving efficient water resource allocation. Water use could be optimized through planning and regulation and market instruments, but implementation and enforcement of these tools rely on strong institutions, policies, and legal systems.

Third, governance capacity constraints limit countries' ability to integrate climate adaptation and water resources management in development planning. Effective water management requires a whole-of-government approach at the national level and regional cooperation for transboundary waters. In reality, water-related planning, investments, and regulation are often scattered across many agencies, requiring close coordination and collaboration across the institutions. Poor governance capacity will hinder water sector performance. The Nepal CCDR, for example, notes that financial resource constraints are compounded by a lack of technical capacity and significant coordination gaps across three levels of government (World Bank 2022e). Ability to address climate challenges is particularly limited in the world's most water-stressed regions, such as the Middle East and North Africa, where some countries are also grappling with ongoing conflicts. Countries with low governance capacity would need significant support for efforts to improve water security and climate resilience.

Key recommendations

CCDRs identify a range of general and country-specific solutions to improve water resources management and build climate resilience (figure 7). Closing the water supply gap requires infrastructure investment but also policy, institutional, and regulatory reforms to improve irrigation and water supply and sanitation services and to increase their financial sustainability. Such measures include strengthening joint regional institutions for water operations, planning, and climate adaptation; stepping up water sector reforms to improve sector efficiency and financial sustainability and access to finance; and strengthening work to achieve universal provision of water, sanitation, and hygiene. Notably, water tariff reform often faces political economy challenges, and it is more likely to be recommended in countries already confronted with water scarcity challenges.

FIGURE 7 Most Frequently Mentioned Water Sector Actions in CCDRs



Source: Analysis is based on 52 completed CCDRs (25 in 2022, 16 in 2023, and 11 in 2024).

Improve access to water supply and sanitation services. The lack of safe drinking water and basic sanitation is known to undermine efforts to combat poverty and disease. Expanding and improving water supply and sanitation infrastructure in underserved areas is critical because this effort has not kept pace with urban growth and is highly affected by climate change. The CCDR for Liberia (World Bank 2024) notes that 27 percent of the population lacks access to basic drinking water supply, 17 percent lacks access to sanitation, and more than 60 percent of the urban population is living in informal settlements where improving sanitation is inherently a challenge. Increased rainfall and flooding, due to climate change, are expected to disrupt water supply in both urban and rural areas, contaminate ground water resources, and increase sanitation vulnerabilities through the increased prevalence of water- and vector-borne diseases like cholera and diarrhea. Small-scale interventions such as contingency planning to adopt alternative sources of drinking water supply (e.g., drilled piped ground water or trucked water connected to an elevated reservoir) and onsite sanitation facilities (e.g., biofill toilets) are encouraged to help communities "live with water," thereby reducing their exposure and vulnerability.

Similarly, leveraging wastewater circularity can improve water security and reduce water resource pollution risks. Inadequate and inefficient wastewater management is leading to widespread environmental pollution. Most cities face severe sustainability and resilience risks regarding long-term water resource availability due to the rapidly expanding population, heavy concentration of industrial and commercial activities, and environmentally unsustainable wastewater management practices. The CCDR for Egypt (World Bank 2022f) recommends that cities focus on strengthening the regulatory enforcement and performance monitoring systems for existing wastewater treatment plants, which in turn would strengthen water quality monitoring, the operational and treatment efficiencies of treatment plants, and GHG mitigation. Mainstreaming water use rationalization with wastewater recycling for industrial and agricultural use would deliver additional economic benefits from water resource circularity while also reducing freshwater stresses for key economic and urban centers.

CCDRs also recommended scaling up innovative solutions such as digital technology. The advancement of digital financial services has become crucial in the water sector, playing a significant role in facilitating tariff and incentive payments and providing accessible credit for individuals and farms to invest in pumps, irrigation systems, and sanitation facilities and to manage climate hazards.[5] The CCDR for Côte d'Ivoire (World Bank 2023c) notes that an extension of digital connectivity coupled with adoption of digital technologies will allow the most vulnerable populations to better prepare and protect themselves before, during, and after climate shocks (table 1).

TABLE 1 Digital Water

CATEGORY	COUNTRY
Smart agriculture, drip irrigation, agricultural research, reservoir management, and water availability forecast systems	Benin, Ethiopia, Ghana, Uzbekistan
Emergency response and alerts, digital infrastructure and apps, port governance, and border management reforms	Côte d'Ivoire, Kenya, Lebanon, Tunisia
Water harvesting and water conservation techniques/ technologies, smart grids and digitalization, integration of digital services into infrastructure	Mozambique, Liberia, Nepal, Türkiye
Surface water and underwater unmanned vehicles that monitor changes in climate and marine ecosystems	Maldives

Source: World Bank Country Climate and Development Reports.

Key adaptation measures should be attentive to water demand management, including reconstruction and modernization of water infrastructure, an increased share of water-saving technologies in industry and agriculture, introduction of water-saving irrigation technologies (drip and in-soil irrigation, sprinkling, local-impulse irrigation, irrigation along furrows, regulation of irrigation of fields), and production of higher-value crops with lower water use (World Bank 2022b,g). CCDRs also discussed the need for better management of political economy constraints and actions that build consensus for and operationalize the user-pay principle for commercial use of water resources.

In terms of mitigation, opportunities exist to improve energy efficiency in water supply, wastewater treatment, and irrigation. Taking advantage of these opportunities would reduce GHG emissions and improve the financial sustainability of services. Other approaches include developing greener transport modes such as waterways, reducing agricultural emissions, and other nature-based solutions to increase carbon sequestration (World Bank 2022h).

The CCDRs concluded that the private sector can play a more prominent role in supporting countries to reduce their investment gap in the water sector. To achieve the SDG targets for universal access to safe water and sanitation, the world is experiencing an annual spending shortfall of between US$131.4 billion and US$140.8 billion (Joseph et al. 2024). While most of the water sector investment comes (and is expected to keep coming) from the public sector, the private sector has an important role to play in providing additional financing and innovative approaches that can help reducing inefficiencies of water service providers and improve productivity of public spending. Performance-based contracts, hybrid public-private financing models, and credit enhancement mechanisms can incentivize private sector participation in niches where private sector know-how is particularly relevant, such as reduction of methane emissions from irrigated rice. Moreover, revenue-generating subsectors that are less susceptible to operating below cost recovery, such as hydropower, are well-suited to attract long-term private investment.

With appropriate policy measures, pricing and risk allocations, investments in water-related urban infrastructure, water, sanitation and waste, and other water-related projects can be either partly or fully financed by the private sector over time. City-level planning and regulatory instruments in the Brazilian cities of São Paulo, Belo Horizonte, and Porto Alegre include practical incentives for private developers to adopt climate-focused solutions, including instruments promoting rainwater infiltration and reservation. In Colombia, the development of a blue taxonomy (as an extension of the green taxonomy) is expected to play a leading role in raising private funding for water-related projects, including wastewater treatment plants, sustainable shipping, ecotourism, and offshore renewable energy. In Azerbaijan, the World Bank concluded that performance-based PPPs for nonrevenue water reduction and management as well as for the operation of wastewater treatment plants can benefit from bringing both critical private sector expertise into the sector and additional resources through the potential use of blended finance.[6] PPPs can also be leveraged to strengthen the resilience of water-related infrastructure in areas such as waterway transport, ports, and hydropower.[7]

Recommendations for scaling up private sector financing for water highlighted in the CCDRs include the following:

- Establishing the enabling conditions for private sector participation and commercial financing, including financial sustainability for the water sector, while ensuring affordability and social protection for the poor and vulnerable. Key measures include introducing economic regulation and cost-recovery pricing mechanisms, repurposing subsidy, institutional restructuring, and establish incentives for service providers to improve operational and financial performance.
- Diversifying and expanding the spectrum of finance solutions such as using blended finance approaches. This includes climate-specific grants, concessional loans, guarantees, and equity investments to reduce the cost of capital—by which the government could leverage public funds to reduce risks and increase returns for the private sector to encourage private sector participation.

Lessons for future CCDRs

The following areas are recommended for improvement in future CCDRs.

- Additional assessments of investment needs, especially for water-related climate adaptation efforts, are required to identify low- to no-regrets investment options in the short to medium term. Although nearly all CCDRs estimated damages from climate change impacts on water resources availability and water-related disasters, not all CCDRs included detailed assessments of water sector investment needs and their benefits.

It is worth estimating such financing needs to understand investment gaps and identify the most cost-effective interventions. Additional upstream assessments are also needed to identify viable business cases for engaging the private sector in water-related climate mitigation and adaptation efforts.

- The existing macro models provide valuable insights into the impact of climate change on the macroeconomy, but they have several limitations in modeling water sector shocks. First, traditional macro-economic models typically rely on average monthly, seasonal, or annual climatic data, which are more suitable for countries with strong storage infrastructure and irrigation facilities to mitigate temporal variations in water distribution. These models are not suitable for economies dependent on rainfed agriculture and are affected by frequent dry spells; even a week-long dry spell at the wrong time of crop development could lead to a failed harvest or food insecurity. Tropical Sub-Saharan African countries such as Ethiopia and Kenya are commonly affected by such phenomena. Second, traditional models often assume that water transfer from one sector to another or from one region to another in response to scarcity is accomplished at little cost to the economy, thereby underestimating the impact of water scarcity. More work is needed to develop hydro-economic models to better transfer hydrological uncertainties to economic impacts.
- Future CCDRs can develop a stronger narrative about the water-jobs nexus. Investment in water security contributes to job creation through multiple channels. Water is a critical input for many economic activities, and ensuring a reliable water supply could expand job demand by boosting productivity for water-dependent and related sectors, such as agriculture, energy, manufacturing, and transportation. In addition, water security is foundational for ensuring better health and education outcomes and thus plays a critical role in boosting labor productivity and supply. Future CCDRs can consider conducting deep dives on the impacts of water on jobs and employment.
- Equally important is the incorporation of transboundary water narratives in CCDRs. More analyses can be included in CCDRs to highlight the implications of droughts for upstream and downstream riparian countries and to illuminate the opportunities and challenges related to transboundary water governance. Specifically, CCDRs can include analysis of the effects of climate change on riparian countries under cooperative and less cooperative scenarios and can identify measures that can be implemented at regional and national levels to enhance climate resilience—measures that reflect costs and risks as well as potential benefits and opportunities. In regions where transboundary commissions do not exist, CCDRs can be used to present a compelling case for establishing transboundary water collaboration.
- CCDRs can emphasize the importance of monitoring the results of water sector investments, especially through the systematic use of remote sensing to overcome data collection weaknesses in the water sector. Additionally, there is scope for systematically improving evidence-based weather and flood forecasting.

The impacts of climate change on numerous countries demand urgent and large-scale interventions. 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*** (Global Challenge Program for Water) is one of six programs that will use replicable and scalable approaches to support countries in addressing development challenges with greater speed and impact. CCDRs can significantly contribute to identifying key priorities for actions under the Global Challenge Program for Water. Successful CCDR implementation will support our commitment to increase delivery speed, scale, and impact.

Endnotes

[1] The reviewed CCDRs: Angola, Arab Republic of Egypt, Argentina, Armenia, Azerbaijan, Bangladesh, Benin, Brazil, Cambodia, Cameroon, Central African Republic, China, Colombia, Côte d'Ivoire, Democratic Republic of Congo, Dominican Republic, Ethiopia, G5 Sahel, Ghana, Guinea-Bissau, Honduras, Indonesia, Iraq, Jordan, Kazakhstan, Kenya, Lebanon, Liberia, Madagascar, Malawi, Maldives, Moldova, Mongolia, Morocco, Mozambique, Nepal, Organization of Eastern Caribbean States, Pacific Atolls, Pakistan, Peru, Philippines, Republic of Congo, Romania, Rwanda, Senegal, South Africa, Tunisia, Türkiye, Uzbekistan, Vietnam, Western Balkans, Zimbabwe. Data cutoff is August 28th, 2024. CCDRs are available at https://www.worldbank.org/en/publication/country-climate-development-reports.

[2] https://www.un.org/sustainabledevelopment/water-and-sanitation/.

[3] While macro-level analyses on the impact of climate change have so far mostly focused on long-term trends in terms of changes in temperature and precipitation, short-term fluctuations in precipitation, such as change in 5-day average, can also impose large shocks to the economy.

[4] The five areas are early warning systems, climate-resilient infrastructure, improved dryland agriculture crop production, global mangrove protection, and investments in making water resources more resilient.

[5] Kenya's digital adoption is relatively high. The CCDR for Kenya (World Bank 2023d) notes that the country's digital water solutions are transforming the way utilities and customers interact. Mobile money is a game-changer for revenue collection, while Internet of Things devices have created new ways to monitor water services and automate processes.

[6] The World Bank has provided technical support to improve water security under the EU-funded Azerbaijan Rapid Technical Assistance Facility, and it is developing an assessment of water supply and sanitation policies, institutions, and regulation for the South Caucasus region.

[7] The hydropower sector has been particularly successful in attracting private investment and is also an enabler for private investment in solar and wind electricity. For example, in Argentina, a water plan has identified investment opportunities for $10 billion in five major multipurpose dams that could help the country increase its hydropower generation capacity (World Bank 2022i); the majority of the investment in new generation capacity is expected to come from the private sector. Waterways is another subsector where private investment is playing a role in increasing climate resilience. In some countries, waterways can play a strategic role for freight transport and supply chain decarbonization. For instance, in Brazil, coastal cabotage and waterway transport represents 14.8 percent of total cargo (World Bank 2023e).

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