Box 2.2 Addressing small-scale farmers' livelihoods in poverty alleviation

Close to 84% of smallholder farms in low- and middle-income countries are located in water-scarce regions, and less than a third have access to irrigation (Ritchie, 2021; FAO, 2021). There is a need for more attention and help to smallholder farmers and the rural poor, in particular women and children, as the role they play contributes to achieving the Sustainable Development Goals as well as conserving local ecosystems. FAO's framework on extreme rural poverty recognizes that conserving and restoring natural resources should directly benefit the rural poor, particularly those living in remote marginalized areas. This is linked to promoting responsible governance of the tenure of resources. Recognizing the legitimate tenure rights of people to use, manage and control land, water, biodiversity, forests and fisheries is fundamental to helping the rural extreme poor adapt to climate change (FAO, 2019).

By increasing knowledge on the role of water in rural livelihoods and adopting participatory approaches centred on smallholder farmers, actions can be focused to build resilience, identify and adapt water technologies, and promote smart investments in water for poverty reduction. International and national partners are developing methodologies based on the concept of livelihood mapping to help investors and policy-makers in prioritizing, planning and implementing water-related interventions in support of smallholder farmers; performing regional and national studies on rural poverty reduction through water-related interventions; and applying water technologies and approaches to increase the impact of development projects targeting poor farmers, with particular attention to women (FAO, n.d.a).

The next generation of investments will need to focus on intensifying agricultural production in a sustainable manner through improved management and governance

Improvements in irrigation (as described above), combined with water reuse, desalination and groundwater recharge, are important strategies for transforming agricultural water management. Additionally, the digitalization of the agricultural sector is increasing the availability of accurate and real-time data for farmers, allowing them to make better decisions on crop choices and water use. Innovations in water-scarce regions have allowed farmers to better control water and fertilizer inputs to improve crop yields (Ghosh et al., 2022, p. 39). Traditional drip irrigation systems, requiring higher capital and energy cost, may not be suited for smallholder farmers in the NENA region with plot sizes ranging from 0.09 ha to 0.76 ha (Sokol et al., 2019). Innovative projects have introduced valves that provide drip irrigation at very low pressures of 0.15 Bar versus the 0.50 to 1.00 Bar needed for a conventional system. These installations use a smaller-capacity pump and a rooftop water tank, allowing for energy savings of up to 50% (Sokol et al., 2019).

Although 70–80% of cropland is not irrigated (FAO, n.d.b), investments in rainfed agriculture are underway and there is scope to improve rainwater retention in order to shift from non-productive water loss (evaporation and runoff) to productive water uptake (transpiration) by crops. Additional and complementary actions supporting the conservation of water in soils include efficient water use and water scarcity management; tech-enabled irrigation systems; and runoff and rainwater collection and storage systems (Ghosh et al., 2022, p. 40).

Agricultural water management has a critical role to play in order to improve resilience across natural and social systems. Equitable access to water, financing, data and technology with institutional and governance support mechanisms must prepare towards a resilient future that embraces water scarcity, systemic changes in availability, and competition for natural resources in order to achieve global prosperity and peace.

References

Blank, S. C. 2001. Globalization, cropping choices, and profitability in American agriculture. *Journal of Agricultural and Applied Economics*, Vol. 33, pp. 315–326. doi.org/10.22004/ag.econ.15013.

Bingen, R. J. and Simpson, B. 1997. Technology transfer and agricultural development in West Africa. Y. S. Lee (ed.), *Technology Transfer and Public Policy*, pp. 76–91. Westport, Conn./London, Quorum Books.

Burek, P., Satoh, Y., Fischer, G., Kahil, M. T., Scherzer, A., Tramberend, S., Nava, L. F., Wada, Y., Eisner, S., Flörke, M., Hanasaki, N., Magnuszewski, P., Cosgrove, B. and Wiberg, D. 2016. *Water Futures and Solution: Fast Track Initiative (Final Report)*. IIASA Working Paper. Laxenburg, Austria, International Institute for Applied Systems Analysis (IIASA). https://pure.iiasa.ac.at/id/eprint/13008/.

CFS (Committee on World Food Security). 2014. *Principles for Responsible Investment in Agriculture and Food Systems*. Rome, FAO/WFP/IFAD (Food and Agriculture Organization of the United Nations/World Food Programme/International Fund for Agricultural Development). www.fao.org/3/a-au866e.pdf.

Cervigni, R., Morris, M., Scandizzo, P. and Savastano, S. 2016. Vulnerability in drylands today. R. Cervigni and M. Morris (eds.), *Confronting Drought in Africa's Drylands: Opportunities for Enhancing Resilience*. Washington, World Bank. https://openknowledge.worldbank.org/handle/10986/23576.

Deininger, K. 2003. *Land Policies for Growth and Poverty Reduction*. World Bank Policy Research Report. Washington, World Bank/Oxford University Press. http://hdl.handle.net/10986/15125. Licence: CC BY 3.0 IGO.

FAO (Food and Agriculture Organization of the United Nations). 2015. *Climate Change and Food Security: Risks and Responses*. Rome, FAO. www.fao.org/3/i5188e/I5188E.pdf.

_____. 2016. *Exploring the Concept of Water Tenure*. Land and Water Discussion Paper No. 10. Rome, FAO. www.fao.org/3/i5435e/i5435e.pdf.

_____. 2017a. *The State of Food and Agriculture: Leveraging Food Systems for Inclusive Rural Transformation*. Rome, FAO. www.fao.org/documents/card/en/c/I7658EN.

_____. 2017b. *The Future of Food and Agriculture: Trends and Challenges*. Rome, FAO. www.fao.org/3/i6583e/i6583e.pdf.

_____. 2018. *The Future of Food and Agriculture: Alternative Pathways to 2050*. Rome, FAO. www.fao.org/3/I8429EN/i8429en.pdf.

_____. 2019. *The State of Food and Agriculture: Moving Forward on Food Loss and Waste Reduction*. Rome, FAO. www.fao.org/3/ca6030en/ca6030en.pdf.

_____. 2020a. *The State of Food and Agriculture 2020: Overcoming Water Challenges in Agriculture*. Rome, FAO. doi.org/10.4060/cb1447en.

_____. 2020b. *Unpacking Water Tenure for Improved Food Security and Sustainable Development*. Land and Water Discussion Paper No.15. Rome, FAO. doi.org/10.4060/cb1230en.

_____. 2021. *The State of the World's Land and Water Resources for Food and Agriculture: Systems at Breaking Point*. Synthesis Report 2021. Rome, FAO. doi.org/10.4060/cb7654en.

_____. 2023. *Biennial Theme 2024-25: Water Resources Management for the Four Betters: Better Production, Better Nutrition, Better Environment and Better Life, to Achieve Agenda 2030 and the Sustainable Development Goals*. FAO Conference, Forty-third Session, Rome, 1–7 July 2023. www.fao.org/3/nm123en/nm123en.pdf.

_____. n.d.a. Water & poverty. Land & Water. FAO website. www.fao.org/land-water/water/watergovernance/water-and-poverty/en/?. (Accessed on 25 October 2023).

_____. n.d.b. Food Systems Assessment: Working towards the SDGs. FAO website. www.fao.org/support-to-investment/our-work/projects/fsa2021/en/. (Accessed on 31 August 2023).

FAO/IFAD/UNICEF/WFP/WHO (Food and Agriculture Organization of the United Nations/International Fund for Agricultural Development/United Nations Children's Fund/World Food Programme/World Health Organization). 2023. *The State of Food Security and Nutrition in the World 2023: Urbanization, Agrifood Systems Transformation and Healthy Diets across the Rural–Urban Continuum*. Rome, FAO. doi.org/10.4060/cc3017en.

FAO/OECD (Food and Agriculture Organization of the United Nations/Organisation for Economic Co-operation and Development). 2021. *Water and Agriculture: An Issues Note Produced for the G20 Presidency of the Kingdom of Saudi Arabia*. Rome, FAO. www.fao.org/3/cb2392en/CB2392EN.pdf.

FAO/UN-Water. 2021. *Progress on the Level of Water Stress: Global Status and Acceleration Needs for SDG Indicator 6.4.2*. Rome, FAO. doi.org/10.4060/cb6241en.

Grossman, A. D., Belete, Y. Z., Boussiba, S., Yogev, U., Posten, C., Ortiz Tena, F., Thomsen, L., Wang, S., Gross, A., Leu, S. and Bernstein, R. 2021. Advanced near-zero waste treatment of food processing wastewater with water, carbon, and nutrient recovery. *Science of the Total Environment*, Vol. 779, Article 146373. doi.org/10.1016/j.scitotenv.2021.146373.

GSMA. 2018. *Enabling Rural Coverage: Regulatory and Policy Recommendations to Foster Mobile Broadband Coverage in Developing Countries*. GSMA. www.gsma.com/mobilefordevelopment/wp-content/uploads/2018/02/Enabling_Rural_Coverage_English_February_2018.pdf.

Ghosh, E., Kemp-Benedict, E., Huber-Lee, A., Nazareth, A. and Oudra, I. 2022. *Investing in Agricultural Water, Sustainably: Recent Trends in Financing Institutions*. FAO Investment Centre – Directions in Investment, No. 7. Rome, FAO. doi.org/10.4060/cc1212en.

Goksu, A., Tremolet, S., Kolker, J. and Kingdom, B. 2017. *Easing the Transition to Commercial Finance for Sustainable Water and Sanitation*. Washington, World Bank. http://hdl.handle.net/10986/27948. Licence: CC BY 3.0 IGO.

Huber-Lee, A., Kemp-Benedict, E., Gosh, E., Nazareth, A. and Oudra, I. 2021. *Investing in Agricultural Water Management: Pathways to a Sustainable Future*. Rome, FAO. doi.org/10.4060/cb8059en.

IFAD (International Fund for Agricultural Development). 2010. *Rural Poverty Report 2011. New Realities, New Challenges: New Opportunities for Tomorrow's Generation*. Rome, IFAD. www.ifad.org/en/web/knowledge/-/publication/rural-poverty-report-2011-print-version-5-0mb-.

Lowder, S., Sánchez, M. V. and Bertini, R. 2021. Which farms feed the world and has farmland become more concentrated? *World Development*, Vol. 142, Art. 105455. doi.org/10.1016/j.worlddev.2021.105455.

McElwee, G. 2008. A taxonomy of entrepreneurial farmers. *International Journal of Entrepreneurship and Small Business*, Vol. 6, No. 3, pp. 465–478. doi.org/10.1504/IJESB.2008.019139.

Nordin, D. S. and Scott, R. V. 2005. *From Prairie Farmer to Entrepreneur: The Transformation of Midwestern Agriculture*. Bloomington, Ind., Indiana University Press.

Poulton, C. and Macartney, J. 2012. Can public–private partnerships leverage private investment in agricultural value chains in Africa? A preliminary review. *World Development*, Vol. 40, No. 1, pp. 96–109. doi.org/10.1016/j.worlddev.2011.05.017.

Rao, V. 2020. *An Empirical Analysis of Factors Responsible for the Use of Capital Market Instruments in Infrastructure Project Finance*. ADBI Working

Paper No. 1101. Tokyo, Asian Development Bank Institute (ADB Intitute). www.adb.org/publications/empirical-analysis-capital-market-instruments-infrastructure-project-finance.

Raes, L., D'Haese, M., Aguirre, N. and Knoke, T. 2016. A portfolio analysis of incentive programmes for conservation, restoration and timber plantations in Southern Ecuador. *Land Use Policy*, Vol. 51, pp. 244–259. doi.org/10.1016/j.landusepol.2015.11.019.

Reardon, T., Tschirley, D., Dolislager, M., Snyder, J., Hu, C. and White, S. 2014. *Urbanization, Diet Change, and Transformation of Food Supply Chains in Asia*. White Michigan State University. Global Center for Food Systems and Innovation. www.fao.org/fileadmin/templates/ags/docs/MUFN/DOCUMENTS/MUS_Reardon_2014.pdf.

Rentschler, J., Salhab, M. and Jafino, B. A. 2022. Flood exposure and poverty in 188 countries. *Nature Communications*, Vol. 13, Article 3527. doi.org/10.1038/s41467-022-30727-4.

Ritchie, H. 2021. Smallholders Produce One-Third of the World's Food, Less than Half of What Many Headlines Claim. OurWorldInData.org. https://ourworldindata.org/smallholder-food-production.

RRI (Rights and Resources Initiative). 2015. *Who Owns the Land in Africa? Formal Recognition of Community-based Land Rights in Sub-Saharan Africa*. Washington, RRI. https://rightsandresources.org/publication/who-owns-the-land-in-africa.

Sokol, J., Amrose, S., Nangia, V., Talozi, S., Brownell, E., Montanaro, G., Abu Naser, K., Mustafa, K. B., Bahri, A., Bouazzama, B., Bouizgaren, A., Mazahrih, N., Moussadek, R., Sikaoui, L. and Winter, A. G. 2019. Energy reduction and uniformity of low-pressure online drip irrigation emitters in field tests. *Water*, Vol. 11, No. 6, Article 1195. doi.org/10.3390/w11061195.

Somkaun, N., Chumnanmak, R., Narongchai, W. and Suppatkul, P. 2019. The transformation from farmer to entrepreneur in Khon Kaen Province, Thailand. *Journal of Mekong Societies*, Vol. 15, No. 3, pp. 95–120. https://so03.tci-thaijo.org/index.php/mekongjournal/article/view/209091.

Townsend, R. F., Ceccacci, I., Cooke, S., Constantine, M. and Moses, G. 2013. *Implementing Agriculture for Development: World Bank Group Agriculture Action Plan (2013-2015)*. Washington, World Bank Group. http://documents.worldbank.org/curated/en/331761468152719470/Implementing-agriculture-for-development-World-Bank-Group-agriculture-action-plan-2013-2015.

Toan, T. D. 2016. Water pricing policy and subsidies to irrigation: A review. *Environmental Processes*, Vol. 3, pp. 1081–1098. doi.org/10.1007/s40710-016-0187-6.

Troell, J. and Keene, S. 2022. *Legal Recognition of Customary Water Tenure in Sub-Saharan Africa: Unpacking the Land–Water Nexus*. IWMI Research Report No. 182. Colombo, International Water Management Institute (IWMI). doi.org/10.5337/2022.215.

United Nations. 2022. *The United Nations World Water Development Report 2022. Groundwater: Making the Invisible Visible*. Paris, United Nations Educational, Scientific and Cultural Organization (UNESCO). https://unesdoc.unesco.org/ark:/48223/pf0000380721?posInSet=1&queryId=268f0bf5-2641-4ff6-896d-d1bdfce78258.

_____. 2023a. *Interactive Dialogue 2: Water for Sustainable Development Concept Paper Prepared by the Secretariat*. 2023 United Nations Conference on the Midterm Comprehensive Review of the Implementation of the Objectives of the International Decade for Action, "Water for Sustainable Development", 2018–2028, New York, 22–24 March 202. https://sdgs.un.org/sites/default/files/2023-01/23-00159%20Concept%20Paper%20UNWC_ID2_Website.pdf.

_____. 2023b. *The United Nations World Water Development Report 2023: Partnerships and Cooperation for Water*. Paris, United Nations Educational, Scientific and Cultural Organization (UNESCO). https://unesdoc.unesco.org/ark:/48223/pf0000384655.

Ward, F. A. 2010. Financing irrigation water management and infrastructure: A review. *International Journal of Water Resources Development*, Vol. 26, No. 3, pp. 321–349. doi.org/10.1080/07900627.2010.489308.

Warner, K., Afifi, T., Henry, K., Rawe, T., Smith, C. and De Sherbinin, A. 2012. *Where the Rain Falls: Climate Change, Food and Livelihood Security, and Migration: An 8-Country Study to Understand Rainfall, Food Security and Human Mobility*. Bonn, Germany, United Nations University Institute for Environment and Human Security (UNU-EHS). https://migration.unu.edu/publications/policy-briefs/where-the-rain-falls-climate-change-food-and-livelihood-security-and-migration.html#:~:text=The%20%C2%AB%20Where%20the%20Rain%20Falls,Asia%2C%20Africa%20and%20Latin%20America.

World Bank. 2011. *Zambia – Irrigation Development and Support Project*. Washington, World Bank Group. http://documents.worldbank.org/curated/en/973891468336580921/Zambia-Irrigation-Development-and-Support-Project.

_____. 2021. Farmer-Led Irrigation Development (FLID). World Bank website. www.worldbank.org/en/topic/water/brief/farmer-led-irrigation-development-flid.

WWAP (World Water Assessment Programme). 2006. *The United Nations World Water Development Report 2. Water: A Shared Responsibility*. Paris/New York, UNESCO/Berghahn Books. https://unesdoc.unesco.org/ark:/48223/pf0000145405.

Chapter 3

Human settlements: WASH, disaster risk reduction and migration

UN-Habitat

Hezekiah Pireh, Avi Sarkar, Simon Okoth and Dewi Hanoum

With contributions from: Sanjaya Bhatia and Kristin Meyer (UNDRR); Ginette Azcona, Antra Bhatt, Guillem Fortuny and Julia Brauchle (UN Women); Amarnath Giriraj, Sandra Ruckstuhl, Charity Osei-Amponsah, Solomie Gebrezgabher and Olufunke Cofie (IWMI); Omar El Hattab, Aidan Cronin, Farai Tunhuma and Monica Ilamazares Casado (UNICEF); Antonio Torres and Eva Mach (IOM); Nidhi Nagabhatla (UNU-CRIS); and Sanae Okamoto (UNU-MERIT)

This chapter focuses on leveraging water in human settlements for community stability and peacebuilding, especially in fragile states and conflict-affected contexts, including its contribution to disaster risk reduction (DRR) and migration management.

While the wealthiest people generally receive safe water and sanitation at a very low price, the poor often pay much higher prices for unsafe services of much lower quality

Understanding the root causes of the tensions and their context, including discrimination and inequalities, is a first step towards peacebuilding. Disparities in access to water, sanitation and hygiene (WASH) services between and within different settlements have heightened inequality, not only in terms of access, but also in terms of the cost of services (World Bank, 2017a; Boakye-Ansah et al., 2019). Such disparities also exist within communities, with certain individuals and groups having lower access to WASH services. While the wealthiest people generally receive safe water and sanitation at a very low price, the poor often pay much higher prices for unsafe services of much lower quality (WWAP, 2019). Inequality in access to water and sanitation services, while not necessarily a direct driver of conflict, presents significant barriers to socio-economic stability and prosperity.

The interrelation between water cooperation, interstate relationships, and post-conflict recovery underlines water's significance in fostering cooperation, managing disputes, and sustaining political stability. The chapter highlights cases where authorities have not given sufficient priority to ensuring equity and non-discrimination in access to water and sanitation services, particularly between formal and informal settlements, rural and urban areas, highest and lowest wealth quintiles, with special attention to marginalized groups. In terms of sanitation, higher-level services such as sewerage extensions have often targeted more high-end communities, deemed to be of higher market value than low-income and informal settlements. This has often led to perpetuating gender inequalities, as well as declines in social stability, individual and collective health and well-being, and economic productivity in the marginalized areas. This is not only hampering human rights, prosperity and stability for those directly affected, but can also spill over to other regions of a country and beyond its borders.

3.1 WASH for displaced and conflict-affected populations

Fragile and conflict-affected contexts are often characterized by unequal access to public services such as water and sanitation (Sadoff et al., 2017). While the human rights to water and sanitation entitle everyone, without discrimination, to affordable services, in practice, communities in conflict-affected contexts often face discrimination and other barriers, including from public authorities who are ultimately responsible for ensuring access to water and sanitation services.

Numerous challenges undermine the provision of WASH services in conflict situations. These challenges often arise due to the breakdown of essential infrastructure, displacement of populations, insecurity, and limited access to resources. Key challenges faced by the WASH sector include:

- **Limited access to safe water:** Conflicts can disrupt water supply systems, restraining access to safe drinking water for both affected populations and humanitarian responders. Contaminated water sources and the absence of proper sanitation facilities increase the risk of waterborne diseases.
- **Sanitation and hygiene issues:** Conflict-related displacement frequently leads to overcrowded living conditions in camps or informal settlements, which often lack adequate sanitation facilities. Inadequate and poorly managed sanitation facilities pose a great risk to the health and well-being of the most vulnerable, especially women, children and persons with disabilities. Poor hygiene practices, such as limited access to soap and clean water for handwashing, contribute to the spread of diseases.

- **Infrastructure damage:** Conflict damages or destroys water and sanitation infrastructure, including water treatment plants, pipelines, wells, and latrines. The restoration of such infrastructure can be challenging due to ongoing hostilities, lack of resources, and obstructed access to affected areas.

- **Insecurity and restricted access:** Conflict zones often pose significant security risks for humanitarian organizations and personnel. Restricted access due to active fighting, presence of landmines, or the use of water sources as strategic targets hampers the delivery of aid and the provision of WASH services.

- **Funding constraints:** Humanitarian response in conflict areas requires substantial financial resources. However, the competing demands for funding across various sectors, limited donor attention, and political priorities often result in inadequate funding for WASH interventions in these situations.

- **Coordination and governance:** Conflict situations may have multiple humanitarian actors operating in the same area, making coordination and governance of WASH efforts complex. Lack of coordination among stakeholders can lead to duplication of efforts, inefficiencies, and gaps in service delivery.

- **Long-term sustainability:** Conflict-affected areas often experience protracted crises, and short-term emergency responses may not address the long-term sustainability of WASH services. Rebuilding infrastructure, capacity development, and establishing local governance mechanisms are critical for ensuring sustainable access to safe water and sanitation.

Damage to water infrastructure increases the amount of time women and girls/children – primary collectors of water – are exposed to the threat of violence, also reducing time for education, work and leisure (UN Women/UNDESA, 2022). Survey data from eight countries in Sub-Saharan Africa showed that people from households in areas experiencing internal disputes over water walked on average 66 minutes to collect water, compared to 30 minutes in areas without such conflict (Pearson et al., 2021). This points to the value of adopting a gender perspective in policies aimed at reducing hardships when safe water supplies are unavailable (UN Women, 2023).

3.2 WASH as a peace-making tool in fragile and conflict-affected contexts

The Organisation for Economic Co-operation and Development (OECD) identifies WASH as a ‘politically neutral’ service system, which can be leveraged as a platform for intercommunal collaboration and partnerships between citizens and government (OECD, 2008; United Nations, 2023). WASH can serve as an important peace dividend if associated with a cessation of violence or with a peace process, and can create incentives for joint action, create space for collaboration, and strengthen community-level trust and social cohesion (UNICEF, 2015). Inclusive, culturally sensitive, accountable and transparent mechanisms for water governance can lead to more effective water management and increased trust in water authorities, thus strengthening peace and the social contract between citizens and authorities (UNICEF, 2020).

There are important social cohesion dimensions to WASH’s contribution to peace among communities, particularly where WASH services and access to water are contested – for example when tensions about water fees exist among communities served by the same water utility, or when water systems cut through areas inhabited by parties in conflict. The collaborative management of WASH services and water resources can generate important social capital (Box 3.1). Using community-based structures to manage water systems (e.g. boreholes, utilities) is common, but this has mostly focused on enhancing the sustainability of WASH infrastructure rather than addressing conflict (Box 3.2). However, such structures can become a peacebuilding asset if they are equipped and supported to perform that role (UNICEF, 2016).

Box 3.1 Addressing intercommunal tensions through WASH Committees in East Darfur (Sudan)

Intercommunal tensions increased in the East Darfur locality of Shariah when an implementing partner (a non-governmental organization (NGO) working on water, sanitation and hygiene (WASH)) changed the location of a new rural supply scheme – a 'water yard' (or motorized borehole). Initially, the water source was planned to be built in Gaar Hagar, but after the geophysical survey, the location was moved to nearby Soraa as it indicated a better water yield. Unfortunately, when the rural groundwater supply scheme was built, the sign was not changed and still said 'Gaar Hagar'. This caused tension between the Gaar Hagar and Soraa communities as people from Gaar Hagar felt they were the rightful owners of the new water yard. The WASH committee in Gaar Hagar had received training on dispute resolution and invited the two communities to a dialogue. After an extensive discussion facilitated by the committee members, it was agreed to establish a joint water management committee to manage and operate the water scheme.

This example highlights the risks of inadvertently fuelling intercommunal tensions due to inopportune (or insensitive) mistakes by implementers, in this case identifying the wrong location name, which led to confusion and competing ownership claims to the water yard.

Source: UNICEF (Forthcoming).

Box 3.2 Promoting peaceful cooperation through WASH in South Kordofan (Sudan)

For years, nomadic communities and the settled communities of Kadugli and Reif Shargi had a mutual agreement on the use of water sources. However, in 2021, a deadly clash between nomads and settlers over damage to a water pump led to nomads being banned from using and accessing water. The local authorities and water, sanitation and hygiene (WASH) sector partners launched a joint intervention to build additional water pumps in areas conducive to settler–nomad interaction. Joint WASH committees conduct regular controls and maintenance and intervene when there is any disagreement or disputes at the water points.

Source: UNICEF (Forthcoming).

An important and potential contribution to peace through WASH relates to accountability and the social contract between service providers and communities. This is particularly important in contexts where there is low trust in government and/or low uptake of health and sanitation measures. "*Supporting conflict-sensitive [WASH] sector governance and policy reform and the development of responsive, inclusive and accountable institutions at national and subnational levels, can improve state–society relations*" (UNICEF, 2015).

Roughly 60% of the potable water in Dakar comes from the Senegal River, delivered through infrastructure managed by the Organization for the Development of the Senegal River (OMVS) (Komara, 2014). Given that water withdrawals in Senegal are projected to increase by 30 to 60% by 2035 and water-related extreme events and pollution in Senegal cost over 10% of the country's annual gross domestic product (GDP) (World Bank, 2022), basin treaties like OMVS could serve as a key instrument to mitigate possible disputes linked to cross-sectoral coordination of water demand and needs, including WASH (see Chapter 7).

3.3 Disaster risk reduction

Due to climate change, more frequent and intense extreme weather events are expected, resulting in a higher incidence of floods and droughts across the planet. Prolonged droughts will also reduce groundwater recharge with subsequent impacts on WASH services, posing a clear danger to development and health (Pimentel-Rodrigues and Silva-Afonso, 2019).

As urban populations increase, more people are concentrated in areas with a high risk of flooding, so that more people and property are at risk from the effects of heavy rainfall and storms. In addition to the physical risks posed by flooding, informal settlements also face significant economic and social challenges in the aftermath of flood events, including loss of income, damage to infrastructure, and limited access to essential services such as healthcare and safe water.

An important and potential contribution to peace through WASH relates to accountability and the social contract between service providers and communities

Disasters caused by natural hazards are estimated to cause an average of over US$300 billion in direct asset losses every year; this estimate increases to US$520 billion when considering the economic loss and well-being of affected people (Hallegatte et al., 2017). Flooding is among the most prevalent water-related disasters affecting people around the world. Water-related disasters can cause households to fall into poverty (Hallegatte et al., 2020), while those already living poverty are often located in high-risk areas, such as on floodplains or in urban areas at high risk of flood (Satterthwaite, 2007). In addition, floods may directly contaminate water, leading to insecure water and WASH services.

Flood risk mitigation measures to support policies and programmes for resilient development climate change adaptation (CCA) and DRR can address the root causes of vulnerability and build resilience to the impacts of flooding. Possible measures include improving access to affordable housing, upgrading infrastructure and services, promoting sustainable land use practices, investing in DRR and climate adaptation strategies, and nature-based solutions (Box 3.3). By addressing these underlying social and economic factors, policy-makers and community leaders can help to build stronger, more resilient communities that are better equipped to cope with the impacts of flooding and other hazards. This can contribute to a more stable and prosperous society, where all members have the opportunity to live in safety and dignity, regardless of their exposure to flood risks.

Making Cities Resilient 2030 (MCR2030)[20] is a unique cross-stakeholder initiative for improving local resilience through advocacy, knowledge- and experience-sharing, city-to-city learning networks, technical expertise, partnerships, and the establishment of connections between multiple layers of government. It makes easy-to-use tools available for enhancing the resilience of cities from water-related hazards. This growing network of over 1,550 cities, covering an urban population of over 480 million people, helps cities access over 300 service providers, offering tools and technical support to increase resilience, especially from water-related disasters.

Box 3.3 Nature-based solutions to mitigate flash floods in Freetown (Sierra Leone)

On August 14, 2017, three days of heavy rains triggered flash floods and a massive landslide in and around Freetown, the capital of Sierra Leone, devastating a large cross-section of the city. An estimated 6,000 people were affected, including 1,141 declared dead or missing and over 3,000 people displaced. While housing, health and the social protection sectors[a] accounted for almost 80% of the total damages and losses, almost every part of the urban economy was affected. The livelihood impacts on communities were widespread and continued to grow as the recovery process commenced. The total value of the assets destroyed by the landslide and floods was estimated by the World Bank (2017b) at US$32 million, while the preliminary cost of resilient recovery needed was estimated at about US$82 million.

To respond to the perennial challenges caused by flooding, the Government of Sierra Leone, in collaboration with the Freetown City Council (FCC) and a host of non-governmental organizations (NGOs) have mobilized local community members who have formed Community Disaster Management Committees (CDMCs), the local level structures responsible for implementation of disaster risk reduction interventions and trained first responders during emergencies. A more recent intervention is the establishment of the Western Areas Peninsular Water Fund, aimed at the ecological restoration of the Western Area District Forest cover in order to retain sediment. This project aims to reduce the water flow and thus the risk of floods, landslides and biodiversity loss, while improving the water supply for the city. The Conservation Scenario proposed by the Water Fund would reduce the expected annual damage costs from flooding across all seven urban watersheds of Freetown by some US$2.05 million, with an average of 74 fewer buildings being inundated compared to the current situation (CRS/TNC, 2021).

[a] The social protection sector encompasses programmes designed to reduce poverty and vulnerability by promoting efficient labour markets, diminishing people's exposure to risks, and enhancing their capacity to manage economic and social risks, such as unemployment, exclusion, sickness, disability and old age.

[20] For more information, please see: mcr2030.undrr.org.

In July 2021, several European countries, including Belgium, Germany and the Kingdom of the Netherlands, were affected by catastrophic floods, causing widespread damage with losses in properties and critical infrastructures, such as water provisioning and power facilities. The total economic costs were estimated at over €10 billion, with more than 200 people killed. These events generated regional momentum to support multidimensional and cross-border efforts towards regional resilience against water-related disasters (UNU-EHS/UNU-CRIS/UNU-MERIT, 2023). Establishing cross-border disaster risk governance requires integrated approaches to water and climate security, including integrating immediate humanitarian response and recovery processes, and improving the long-term resilience of water provisioning systems.

3.4 Migration and forcibly displaced populations

The number of migrants and displaced persons increases every year. The *Global Report on Internal Displacement 2023* (GRID) revealed that at the end of 2022, the number of internally displaced persons reached its highest level ever recorded, with 71.1 million people displaced worldwide, of which 88% due to conflict and violence (IDMC, 2023).

Research shows, for instance, that in some parts of the Sahel, declining availability of water is a significant driver of migration (OHCHR, 2022). The Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2023, p. 6) found that *"climate and weather extremes are increasingly driving displacement in Africa, Asia, North America (high confidence), and Central and South America (medium confidence)"*.

Year after year, internal disaster-related displacements outnumber conflict-related displacement, as evidenced by the annual GRID reports. Most of this disaster-related displacement is caused by weather-related events linked to water extremes (IDMC, 2022). In the absence of sufficient climate action, the World Bank estimates that, by 2050, 216 million people may be forced to move due to impacts of climate change. Most of these movements are predicted to be within country borders (Clement et al., 2021).

Year after year, internal disaster-related displacements outnumber conflict-related displacement

Water scarcity and prolonged droughts can heighten the risks of violence against displaced women and girls, and the imposition of child marriage (OCHA, 2022). In Somalia, evidence suggests a 200% increase in gender-based violence among displaced people, particularly intimate partner violence and rape. The risk of harmful practices, such as child marriage and female genital mutilation, is also compounded (CARE, 2022).

Resource scarcity, environmental degradation and unsustainable environmental management practices can also contribute to the decision to migrate, either to save one's life or to find new livelihoods. Lack of water security, for example, has been identified as one of the key drivers of migration, as it undermines people's everyday existence and livelihood opportunities (Mach, 2017). In another study, water deficits were linked to a 10% increase in global migration between 1970–2000 (Zaveri et al., 2021). However, "*the migration response to rainfall deficits varies significantly depending on country income, with the poorest 80% less likely to migrate in the face of these shocks. This is because migration is often a costly endeavour (...) For the most vulnerable members of society, the migration option may therefore not be available.*" (Zaveri et al., 2021, p. 7).

Water insecurity can exacerbate conflicts and drive displacement, particularly in regions where water resources are limited or unevenly distributed. Moreover, reduced precipitation could further diminish the availability and productivity of agricultural land in some places, putting the livelihoods of millions of households at risk (Wodon et al., 2014; Pons, 2021).

"There is growing evidence that climate extremes are having a devastating impact on agriculture in Central America, affecting the livelihoods of millions of farmers and serving as a driver of migration from the region" (Pons, 2021, p. 1). This is also the case for agricultural pastoralist communities in Northern Kenya and other places where migration has always

been a necessary part of life, as people needed to follow fresh water and pastures in accordance with the seasons. As a result of arid conditions, many pastoralists have been displaced from their communities and forced to find alternative livelihoods (Mach, 2017).

Moving towards a peaceful, water-secure future involves vulnerability mapping, early warning systems for drying conditions, and building resilient water infrastructure. Migration will remain an important adaptation strategy for some young people, particularly in contexts where climate change hinders economic opportunities and interacts with conflict and fragility (UNICEF/IOM, 2021). Displacement can in turn contribute to water insecurity by increasing the burden on water systems and resources in settlement locations. For example, the conflict in Ethiopia's Tigray region has led to the internal displacement of over 2 million people, many of whom are living in camps or informal settlements with limited access to water and sanitation facilities (IOM, 2021).

Approximately 6.8 million Syrians continue to live as refugees worldwide, of whom 5.5 million are hosted in neighbouring countries (UNHCR, 2023). The arrival locations in those countries are often in urban areas, which are, as a consequence, under strain to ensure the delivery of basic services, such as access to safe water and sanitation, to migrant and host communities (UNICEF, 2019).

Conflict sensitivity[21] can support efforts to integrate displaced communities into national WASH systems and to provide services equitably (Box 3.4).

Box 3.4 Strengthening conflict sensitivity in an integrated host–refugee water utility in Itang, Gambella region (Ethiopia)

The integrated host–refugee water utility scheme in Itang, Gambella (Ethiopia), was kick-started in 2014. In response to increased tensions and incidents of sabotage disrupting water supply and to inform an 'optimization phase' foreseen in programme implementation, a conflict sensitivity assessment was implemented in 2020–2021. The assessment sought to identify the causes behind incidents of conflict, in order to help the water utility governance bodies address the situation.

Consultations with key stakeholders and community members identified conflict dynamics, not only between host and refugee communities, but also within local communities about the utility benefiting 'outsiders' (Ethiopians not originally from Gambella) brought in to work on the utility as well as business owners connected to the water supply, which is located along one of the main trading roads. Local communities felt that 'outsiders' and refugees were benefiting from the utility and this fuelled grievances. Efforts were made to strengthen the risk management capacity of the utility, including a 'contingency plan and risk register' to address service gaps as well as strengthened grievance management and governance mechanisms. There was a decrease in conflict incidents and an improvement in collaborative engagement of the key stakeholders.

Source: UNICEF (Forthcoming, p. 58).

Factoring in the rights to water and sanitation while planning for water-secure futures for host and migrant settlements is in line with the vision of the Global Compact for Migration (General Assembly of the United Nations, 2019a) and the Global Compact for Refugees (General Assembly of the United Nations, 2018; 2019b).

---

21 *"Conflict sensitivity is an approach to ensure that interventions do not unintentionally contribute to conflict, but rather, strengthen opportunities for peace and inclusion"* (Government of Canada, n.d.).

References

Amarnath, G., Alahacoon, N., Smakhtin, V. and Aggarwal, P. 2017. *Mapping Multiple Climate-related Hazards in South Asia*. IWMI Research Report 170. Colombo, International Water Management Institute (IWMI). doi.org/10.5337/2017.207.

Boakye-Ansah, A. S., Schwartz, K.and Zwarteveen, M. 2019. Unravelling pro-poor water services: what does it mean and why is it so popular? *Journal of Water, Sanitation and Hygiene for Development*, Vol. 9, No. 2, pp. 187–197. doi.org/10.2166/washdev.2019.086.

CARE. 2022. Somalia: Women and Girls Left Vulnerable in Worsening Drought. Press release, 14 October 2022. CARE website. www.care-international.org/news/somalia-women-and-girls-left-vulnerable-worsening-drought.

Clement, V., Rigaud, K. K., De Sherbinin, A., Jones, B., Adamo, S., Schewe, J., Sadiq, N. and Shabahat, E. 2021. *Groundswell Part 2: Acting on Internal Climate Migration*. Washington, World Bank. http://hdl.handle.net/10986/36248 Licence: CC BY 3.0 IGO.

CRS/TNC (Catholic Relief Services/The Nature Conservancy), 2021. *Western Area Peninsula Water Fund Assessing the Return on Investment for Nature-Based Solutions for The Western Area Peninsula and Freetown, Sierra Leone Final Business Case: March 2021*. www.crs.org/sites/default/files/wapwf_business_case_report_final.pdf.

General Assembly of the United Nations. 2018. *Report of the United Nations High Commissioner for Refugees. Part II Global compact on refugees*. Seventy-third session, A/73/12 (Part II). www.unhcr.org/media/report-united-nations-high-commissioner-refugees-part-ii-global-compact-refugees.

_____. 2019a. Global Compact for Safe, Orderly and Regular Migration. Resolution adopted by the General Assembly on 19 December 2018, seventy-third session. A/RES/73/195. www.iom.int/resources/global-compact-safe-orderly-and-regular-migration/res/73/195.

_____. 2019b. Office of the United Nations High Commissioner for Refugees. Resolution adopted by the General Assembly on 17 December 2018, seventy-third session. A/RES/73/151. www.unhcr.org/us/media/resolution-adopted-general-assembly-17-december-2018.

Government of Canada. n.d. Tip Sheet on Conflict Sensitivity. Government of Canada website. https://www.international.gc.ca/world-monde/funding-financement/conflict_sensitivity-sensibilite_conflits.aspx?lang=eng.

Hallegatte, S., Vogt-Schilb, A. Bangalore, M. and Rozenberg, J. 2017. *Unbreakable: Building the Resilience of the Poor in the Face of Natural Disasters. Climate Change and Development*. Washington, World Bank. http://hdl.handle.net/10986/25335. Licence: CC BY 3.0 IGO.

Hallegatte, S., Vogt-Schilb, A., Rozenberg, J., Bangalore, M. and Beaudet, C. 2020. From poverty to disaster and back: a review of the literature. *Economics of Disasters and Climate Change*, Vol. 4, No. 1, pp. 223–247. doi.org/10.1007/s41885-020-00060-5.

IDMC (Internal Displacement Monitoring Centre). 2022. *Global Report on Internal Displacement 2022. Children and Youth in Internal Displacement*. Geneva, IDMC. www.internal-displacement.org/global-report/grid2022/.

_____. 2023. Global Report on Internal Displacement 2023. Internal Displacement and Food Security. Geneva, IDMC. www.internal-displacement.org/global-report/grid2023/.

IOM (International Organization for Migration). 2021. Displacement Tracking Matrix (DTM) – Emergency Site Assessment: Northern Ethiopia Crisis 8. Data Collection: 27 July–4 October 2021. IOM. https://dtm.iom.int/sites/g/files/tmzbdl1461/files/reports/DTM%20Ethiopia%20Emergency%20Site%20Assessment%20Round%208%20Report_3.pdf.

_____. n.d. Emergency Manual. Humanitarian Development Peace Nexus (HDPN). IOM website. https://emergencymanual.iom.int/humanitarian-development-peace-nexus-hdpn.

IPCC (Intergovernmental Panel on Climate Change). 2023. Summary for Policymakers. Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. Geneva, IPCC. doi.org/10.59327/IPCC/AR6-9789291691647.001.

Komara, K. 2014. Setting the Example for Cooperative Management of Transboundary Water Resources in West Africa. World Bank Blogs, July 27, 2014. World Bank Blogs. https://blogs.worldbank.org/nasikiliza/setting-example-cooperative-management-transboundary-water-resources-west-africa.

Mach, E. 2017. *Water and Migration: How far would you go for water?* International Organization for Migration (IOM). https://environmentalmigration.iom.int/sites/g/files/tmzbdl1411/files/documents/2023-03/Water%20and%20migration.pdf.

OCHA (UN Office for the Coordination of Humanitarian Affairs). 2022. *Horn of Africa Drought: Regional Humanitarian Overview & Call to Action*. United Nations. https://reliefweb.int/report/ethiopia/horn-africa-drought-regional-humanitarian-overview-call-action-revised-21-september-2022.

OECD (Organisation for Economic Co-Operation and Development). 2008. *Service Delivery in Fragile Situations: Key Concepts, Findings and Lessons*. OECD/DAC Discussion Paper. Paris, OECD. www.oecd.org/dac/conflict-fragility-resilience/docs/40886707.pdf.

OHCHR (Office of the United Nations High Commissioner for Human Rights). 2022. *Advancing a Rights-Based Approach to Climate Change Resilience and Migration in the Sahel*. New York, United Nations. www.ohchr.org/sites/default/files/2022-11/Climate-Change-migration-Sahel-report.pdf.

Pearson, A. L., Mack, E. A., Ross, A., Marcantonio, R., Zimmer, A., Bunting, E. L., Smith, A. C., Miller, J. D., Evans, T. and the HWISE Research Coordination Network. 2021. Interpersonal conflict over water is associated with household demographics, domains of water insecurity, and regional conflict: Evidence from nine sites across eight sub-Saharan African countries. *Water*, Vol. 13, No. 9, Article 1150. doi.org/10.3390/w13091150.

Pimentel-Rodrigues, C. and Silva-Afonso, A. 2019. Contributions of water-related building installations to urban strategies for mitigation and adaptation to face climate change. *Applied Sciences*, Vol. 9, Article 3575. doi.org/10.3390/app9173575.

Pons, D. 2021. *Climate Extremes, Food Insecurity, and Migration in Central America: A Complicated Nexus*. Migration Policy Institute (MPI). www.migrationpolicy.org/article/climate-food-insecurity-migration-central-america-guatemala.

Sadoff, C. W., Borgomeo, E. and de Waal, D. 2017. *Turbulent Waters: Pursuing Water Security in Fragile Contexts*. Washington, World Bank. http://hdl.handle.net/10986/26207. Licence: CC BY 3.0 IGO.

Satterthwaite, D., Huq, S., Pelling, M., Reid, H. and Lankao, P. R. 2007. *Adapting to Climate Change in Urban Areas: The Possibilities and Constraints in Low- and Middle-Income Nations*. Human Settlements Working Paper. International Institute for Environment and Development (IIED). https://www.iied.org/10549iied.

United Nations. 2023. *The United Nations World Water Development Report 2023: Partnerships and Cooperation for Water*. Paris, United Nations Educational, Scientific and Cultural Organization (UNESCO). https://unesdoc.unesco.org/ark:/48223/pf0000384655.

United Nations/World Bank. 2018. *Pathways for Peace: Inclusive Approaches to Preventing Violent Conflict*. Washington, World Bank. http://hdl.handle.net/10986/28337. Licence: CC BY 3.0 IGO.

UNDP (United Nations Development Programme). n.d. Advancing gender equality in NDCs: progress and higher ambitions. Data Futures Platform. UNDP website. https://data.undp.org/content/gender-and-ndc/.

UNHCR (Office of the United Nations High Commissioner for Refugees). 2023. Twelve years on, Syrian refugees face deepening debt and hunger. UNHCR website. www.unhcr.org/news/twelve-years-syrian-refugees-face-deepening-debt-and-hunger.

UNICEF (United Nations Children's Fund). 2015. *The Contribution of Social Services to Peacebuilding and Resilience: Evolving Theory and Practice*.

_____. 2016. *Conflict Sensitivity and Peacebuilding Programming Guide*. UNICEF. www.unicef.org/media/96576/file/Programming-Guide-Conflict-Sensitivity-and-Peacebuilding.pdf.

_____. 2019. *Water Under Fire – Volume 1: Emergencies, Development and Peace in Fragile and Conflict-Affected Contexts*. New York, UNICEF. www.unicef.org/media/58121/file/Water-under-fire-volume-1-2019.pdf.

_____. 2020. *UNICEF and Sustaining Peace: Strengthening the Socio-Economic Foundations of Peace through Education, Young People's Engagement & WASH*. UNICEF Thematic Paper Contribution; United Nations Secretary-General's 2020 Peacebuilding & Sustaining Peace Report. New York, UNICEF. www.unicef.org/media/96551/file/Thematic-paper-for-2020-sg-report-mf.pdf.

_____. Forthcoming. *WASH for Peace – Conflict Sensitivity and Peacebuilding Guidance and Tools for the WASH Sector*. UNICEF.

_____. n.d. Water, sanitation and hygiene – Every child has a right to water, sanitation and a safe and clean community. UNICEF website. www.unicef.org/drcongo/en/what-we-do/water-sanitation-and-hygiene. (Accessed on 27 September 2023).

UNU-EHS/UNU-CRIS/UNU-MERIT (United Nations University-Institute for Environment and Human Security/United Nations University-Institute on Comparative Regional Integration Studies/United Nations University-Maastricht Economic and Social Research Institute on Innovation and Technology). 2023. *Building Climate Resilience: Lessons from the 2021 Floods in Western Europe*. Bonn/Brugge/Maastricht, Germany/Belgium/The Netherlands, UNU-EHS/UNU-CRIS/UNU-MERIT. https://collections.unu.edu/view/UNU:9123#viewAttachments.

UN Women. 2023. *Spotlight on Goal 6: From Commodity to Common Good: A Feminist Agenda to Tackle the World's Water Crisis*. New York, UN Women. www.unwomen.org/en/digital-library/publications/2023/07/from-commodity-to-common-good-a-feminist-agenda-to-tackle-the-worlds-water-crisis.

UN Women/UNDESA. 2022. *Progress on the Sustainable Development Goals. The Gender Snapshot 2022*. New York, UN Women/UNDESA. www.unwomen.org/sites/default/files/2022-09/Progress-on-the-sustainable-development-goals-the-gender-snapshot-2022-en_0.pdf.

Urban ARK (Urban African Risk Knowledge). 2017. Urban Risk in Freetown's Informal Settlements: Making the Invisible Visible. Briefing No.6 April 2017. https://www.iied.org/g04141.

Wodon, Q., Liverani, A., Joseph, G. and Bougnoux, N. (eds.). 2014. *Climate Change and Migration: Evidence from the Middle East and North Africa*. A World Bank Study. Washington, World Bank. doi.org/10.1596/978-0-8213-9971-2.

World Bank. 2017a. *Reducing Inequalities in Water Supply, Sanitation, and Hygiene in the Era of the Sustainable Development Goals: Synthesis Report of the WASH Poverty Diagnostic Initiative*. WASH Synthesis Report. Washington, World Bank. http://hdl.handle.net/10986/27831. Licence: CC BY 3.0 IGO.

_____. 2017b. *Sierra Leone: Rapid Damage and Loss Assessment of August 14th, 2017, Landslide and Floods in the Western Area*. Washington, World Bank. http://hdl.handle.net/10986/28836. Licence: CC BY 3.0 IGO.

_____. 2022. *Senegal – Challenges and Recommendations for Water Security in Senegal at National Level and in the Dakar-Mbour-Thiès Triangle*. Washington, World Bank Group. http://documents.worldbank.org/curated/en/099625003082251396/P1722330bb79db04d0993305b34176c0341.

WWAP (UNESCO World Water Assessment Programme). 2019. *The United Nations World Water Development Report 2019: Leaving No One Behind*. Paris, UNESCO. https://unesdoc.unesco.org/ark:/48223/pf0000367306.

Zaveri, E., Russ, J., Khan, A., Damania, R., Borgomeo, E. and Jägerskog, A. 2021. *Ebb and Flow, Volume 1: Water, Migration, and Development*. Washington, World Bank. http://hdl.handle.net/10986/36089. Licence: CC BY 3.0 IGO.

Chapter 4

Industry

UNIDO

John Payne

Decoupling water from industrial productivity benefits both industry and those who would benefit from improved water quality and availability

Industry has the capacity – material, human and financial – and consequently the ability to shape and increase economic prosperity, while simultaneously influencing and improving social well-being and environmental integrity (see Box 1.2). It is estimated that corporate supply chains account for two thirds of all water consumption (TNC, n.d.) and that 70% of the world's freshwater use and pollution is affected by seven major sectors – food, textile, energy, industry, chemicals, pharmaceuticals and mining (CDP, 2018). Decoupling water from industrial productivity, in other words reducing industry's leverage over water, will, in the long run, benefits both industry and those who would benefit from improved water quality and availability, particularly in accomplishing several targets of Sustainable Development Goal (SDG) 6.

Linkages between economic growth and water security are difficult to demonstrate, and there appears to be little correlation between a country's per capita gross domestic product (GDP) and its water availability (see Figure P.9). Water facilitates industry but does not create GDP – some industries use little water but have a big contribution to GDP and vice versa. This said, most forms of production involve the use of water, so the effect of water can be more direct: no water means no production.

4.1 Interactions and impacts with water

Industry has a mutual interaction with water, affecting and being affected by freshwater. Industry uses a significant quantity of water, polluting it and harming ecosystems. At the same time, water availability (i.e. scarcity), quality and accessibility generate risks for industry, exposing it to supply chain disruptions, while climate change multiplies the occurrence and impacts of floods and droughts. The textile, apparel and luxury goods; metals and mining; and high tech and electronics industries are significant examples (Ceres, 2022). The cost–benefit ratio of risk mitigation vs. remediation has been estimated at five to one (CDP, 2021).[22]

4.1.1 Costs of water risks

Water risks that could significantly affect business were noted by almost 70% of the firms reporting to a CDP survey (CDP, 2022). The total costs to operations and supply chains might be as high as US$225 billion. In Chile, BHP Billiton and Rio Tinto invested US$3 billion in a desalination plant for a sustainable and continuous water supply for mining in the Atacama Desert and to reduce dependence on local aquifers (Water Technology, 2013). The CDP (2022) warns that water insecurity may affect the value of companies significantly, and assets may be stranded in water-stressed regions.

An analysis by Trucost (a division of S&P; Bernick, 2017) found reported water risks of about US$126 billion, which may even become US$439 billion if non-reporting companies are included. The risks came from higher operational costs linked to deteriorating water quality and supply disruption. If companies had to absorb all the costs for decreased water allocations, increased treatment and stronger effluent discharge regulations, average profits could decrease between 18% (chemical sector) and 116% (food and beverage sector).

4.1.2 Water quantity

It can be inferred that industry uses approximately 7% of the world's freshwater withdrawals, based on data that industry and energy together use about 17% (Ritchie and Roser, 2017)

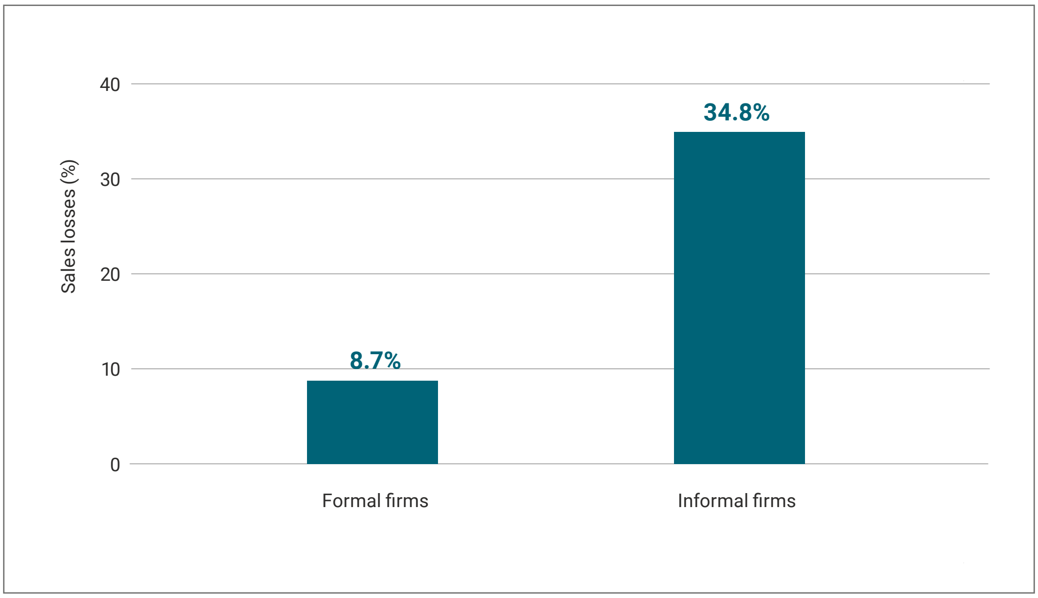
---

22 *"In 2020, the total potential financial impact of reported water risks was up to US$301 billion; while responders reported that the money required to mitigate those risks was only US$55 billion. The potential financial impact reported is equivalent to the entire GDP of Pakistan"* (CDP, 2021, p. 12 and sources 11 and 12 cited in the footnote therein).

and that energy uses approximately 10% (IEA, 2016).[23] Much of the operational risk is in sourcing and supply chains (McKinsey & Company, 2009). There may be a trend towards decreasing water withdrawals by industry; about two thirds of companies that are highly dependent on water reported about the same or lower withdrawals from 2019 to 2020 (CDP, 2021).

Companies, particularly small ones (which can represent a large number of employers in developing countries), see large declines in sales and employment "*when urban water services are disrupted" (*Damania et al., 2017, p. 3). It was noted that "*dry shocks*" were found to cost two to four times more than "*wet shocks*" in terms of lost income. Rainfall shocks can affect companies in many ways, including causing the "*health impacts and power outages*" that are associated with droughts. A 6-year survey of over 16,000 formal firms in over 100 economies found that, in a typical month, an average firm would experience a sales loss of 8.7% for every additional water outage. However, for informal firms – *"a ubiquitous form of economic enterprise in developing countries" (*Damania et al., 2017, p. 52) – across 18 economies in Africa, South Asia and Latin America, the sales loss was 34.8% (Figure 4.1). Companies may pay bribes where water outages are frequent, but this practice does not necessarily lead to improvements in service (Box 4.1).

Figure 4.1
Sales losses as a result of each additional water shortage in a month, as experienced by an average firm, 2009–2015



Source: Damania et al. (2017, fig. 4.4, p. 55).

Some of the largest industrial users are most responsible for groundwater depletion. These include food and beverage, textiles, and apparel (particularly in India, Brazil, Central Asia and parts of the United States of America (USA), mainly due to cotton production), and metals and mining (Ceres, 2022).

[23] As noted in United Nations (2023), Chapter 5, industrial withdrawals reported in the AQUASTAT database from the United Nations Food and Agriculture Organization (FAO) are limited to 'self-supplied water' (AQUASTAT, n.d.). Total industrial water use is likely higher, since the fraction of publicly supplied water used by industry is included in municipal water withdrawals.

Box 4.1 Water supply and bribery

Bribery can thrive where water governance is poor. Yet, surveys show that companies that make such payments are more likely to face water shortages. "*The … data show that firms that make an informal payment or gift to obtain a water connection are more likely to face water shortages than firms that do not. Estimates indicate that 26% of firms experiencing water shortages made informal payments to obtain a connection, whereas only 17% of firms that did not experience shortages made such payments.*" This suggests that a badly managed water utility may be more open to bribery, and/or that weak governance results in inadequate water service. Either way, some firms need to pay bribes to get water service, which results in the loss of income required for improvements and maintenance of public infrastructure.

Source: Damania et al. (2017, Box 4.1, p. 54).

4.1.3 Water quality and pollution

Economic growth (as measured by GDP) can be lowered by as much as a third by pollution released upstream from a centre of production (Damania et al., 2019). The two following examples show how industrial pollution can be addressed to improve water quality.

The mining and metals industry is the largest metal polluter overall. However, the information technology sector, which makes semiconductors, circuit boards and batteries, also releases metals such as mercury, copper, iron, zinc, nickel, chromium, lead, tungsten and lithium in wastewater and through leaching of E-waste. Metals are persistent in lakes and rivers and can bioaccumulate, damaging ecosystems and endangering human health (Ceres, 2022).

A fifth of industrial water pollution globally is produced by textile mills (NRDC, 2016 as cited in CDP, 2020). The second-largest water polluter globally is textile dyeing (UNEP, 2018 as cited in CDP, 2020). At each stage of textile processing, there is the risk that contaminants are released that are harmful to both the environment and human health (Weiss et al., 2016 as cited in CDP, 2020).

4.2 Methods of leveraging

The previous sections have given an overview of how water scarcity (quantity) and pollution (quality) can considerably impact industry. If industry manages to do more with less, then water quantity and quality will be improved for the benefit of other users who in turn will have a better opportunity to prosper.

For industry to manage and use water in a sustainable way, it needs to decouple the relationship between water and production, using a variety of methods to combine economic and environmental gains. It has been reported that "*global trends have pointed to a relative decoupling of water – that is, the rate of water resource use is increasing at a rate slower than that of economic growth.*" (UNEP, 2015a, p. 5). This observation is supported by data from the USA, where GDP from 1900 to the mid-1990s grew 20 times whereas water use increased 10 times and declined after 1985 (Gleick, 2002). Achieving further gains will require a three-pronged conjunctive approach, with technological innovation and good water stewardship from industry, a conducive policy and regulation framework from government, and a suitable financing and investment strategy.

4.2.1 Water footprints

Industry needs to know the water use in its facilities and along its supply chains. Product water footprints[24] measure the volume of water consumed and polluted for each unit produced and reflect the efficiency of water use (Water Footprint Network, n.d.). As such, a company can identify steps in their production and supply chains where their products' water footprints can be reduced.

[24] "*The water footprint of a product is the amount of water that is consumed and polluted in all processing stages of its production. A product water footprint tells us how much pressure that product has put on freshwater resources*". It is generally measured in volume of water (e.g. m^3) per mass of production (e.g. kg) (Water Footprint Network, n.d.).

4.2.2 Technology

The customary linear flow of water in industry, from withdrawal and use to wastewater discharge, does not generally favour reuse and recycling (UNEP, 2015b). However, there are many established technologies for using less (lower withdrawals and consumption) or for reusing and recycling water. Approaches to improve water use efficiency include modifications in materials, processes and equipment (AFED, 2014). There are other drivers within industry than can lead to water reuse (UNEP, 2015b). Technical measures are outlined in Box 4.2. Potential savings in water consumption via closed loop reuse, recycling with treatment and wash water reuse can be significant (AFED, 2014). Steel production, for example, consumed 200 to 300 tonnes of water per tonne of steel in the 1930s and 1940s, but over time this was reduced to 2 to 3 tonnes (Gleick, 2002).

4.2.3 Wastewater

Through reuse, recycling and resource recovery, wastewater was identified as a "*reliable alternative source of water*" and part of the solution for water availability issues. For industry, wastewater can provide a sustainable source of energy, nutrients and by-products (WWAP, 2017). A win–win situation is possible where harmful discharges are reduced and the demand for freshwater decreased. For example, the Indian company Tata Chemicals cut its use of groundwater by 99.4% within a year thanks to improved recycling and water management (CDP, 2020).

However, there remains much room for improvement. In one study, only about half the respondents were monitoring their wastewater, and less than a half were monitoring its quality (CDP, 2020).

4.2.4 Eco-industrial parks

Wastewater is a major focal point in eco-industrial parks (EIPs) where, using the concept of 'industrial symbiosis', it may cascade through several industries, producing savings in treatment costs along the way, particularly for small and medium-sized enterprises (SMEs). EIPs are part of the circular economy, which incorporates inclusive and sustainable industrial development (ISID) with a significant focus on water efficiency, where the same water is used repeatedly. Perhaps the best-known is the Kalundborg Industrial Symbiosis in Denmark (WWAP, 2017, Chapter 6, Box 6.4, p. 66) where the cascading of water annually saves 1 million m^3 of surface water and 2.9 million m^3 of groundwater, reducing wastewater output by 200,000 m^3 (Domenech and Davies, 2011). EIP pilot projects in developing and emerging economies saved about 2 million m^3 annually between 2012 and 2018 (UNIDO, 2019). Moreover, performance requirements are set out in a framework for EIPs. Wastewater, for instance, has a target of 100% treatment, with 25% responsible use in or outside the EIP (UNIDO/World Bank Group/GIZ, 2021).

4.2.5 Water-smart approaches

Water-smart approaches include zero water withdrawal, zero wastewater discharge, zero liquid discharge, dry tailing disposal techniques in mining, and 'dry' personal care products. For example, Formosa Taffeta implemented a fabric dyeing technique that uses artificial intelligence to determine the most efficient dyeing 'curve', significantly reducing water, energy and raw material consumption, as well as costs. The financial benefits can be substantial: Unilever has estimated US$2.2 to US$3.4 billion in sales by 2025 for water-smart personal care products (CDP, 2021).

4.2.6 Switching to renewable energy

Switching to renewable energy can reduce both water use and carbon emissions (Chapter 5). In the chemical and food and beverage processing industries (in over 100 countries), a 50% increase in renewable energy could result in 60% reduction in water consumption and an even bigger impact on emissions (Bryan et al., 2021).

Box 4.2 Technologies for efficient water use

Leak detection – checking underground tanks, piping, distribution networks, water equipment and particularly high-pressure steam systems.

Heating and cooling – by using heat optimization, cascading heat use, water-free heat transfer, and better-quality water to avoid heat losses. Plants may also benefit from centralized heating and cooling in eco-industrial parks.

Cooling towers – optimizing losses with variable-speed water cooling fans, minimizing splash and drift losses, and using treated wastewater.

Water-free systems – using air, mineral oils or special chemicals to transfer heat.

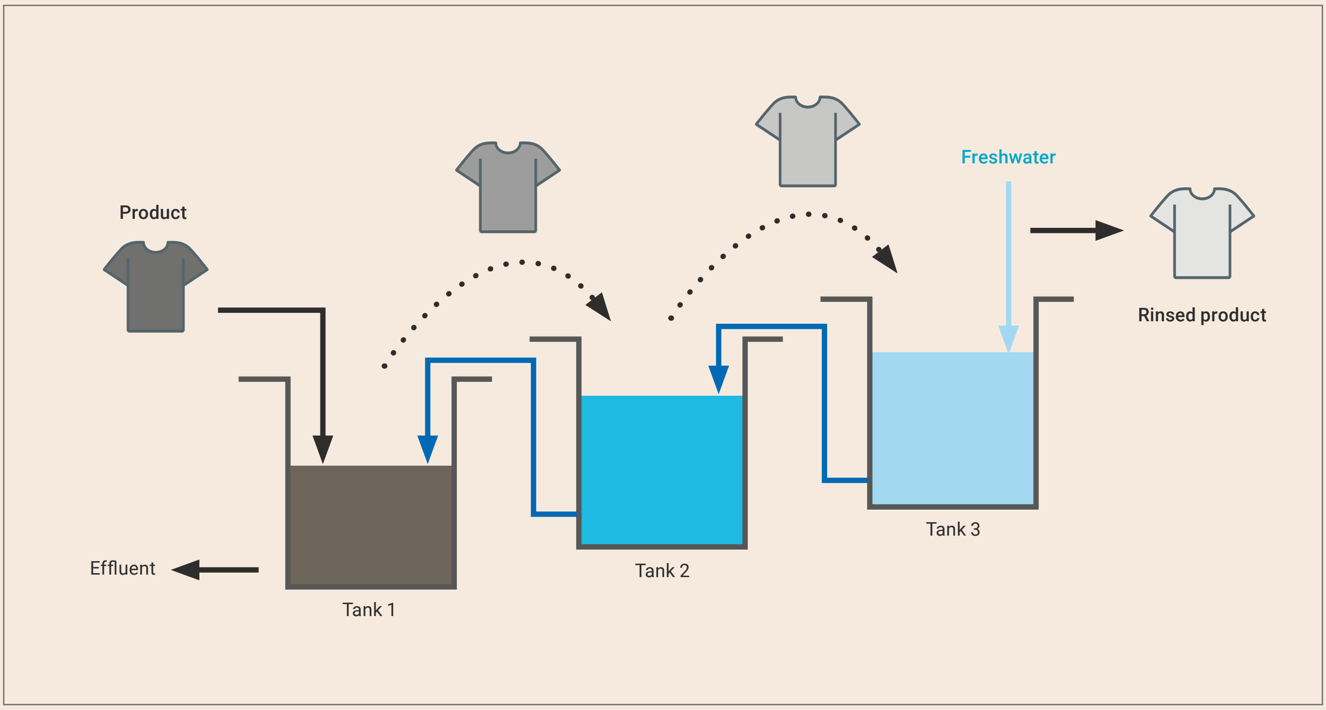
Recirculating systems – heat exchangers to allow water recirculation in a closed system.

Water quality monitoring – impurities that accumulate affect heat transfer, so proper monitoring can lead to major savings.

Recycling blow-down – by using treatment for impurities.

Rinsing and cleaning – such as counter-current washing (figure) in the opposite direction to product flow; mechanical pre-rinsing using air blowing, gravity or centrifuging to reduce rinsing water; use of chemicals and heat.

Counter-current rinsing



Source: AFED (2014, fig. 2.3, p. 49).

Equipment and space cleaning – mechanical pre-cleaning using brushes, scrapers and so on reduces water use and may allow some product recovery; pressurized cleaning can reduce water use by up to 50%; cleaning in place (CIP); use of triggered self-shut-off nozzles; use of steam or hot water.

Transporting products – in some cases wastewater can be used; alternatively, there may be mechanical or pneumatic methods.

Source: Adapted from UNEP (2015b, Box 4.2, p. 40, citing AFED 2010; 2014).

4.2.7 Industry 4.0

The Fourth Industrial Revolution (Industry 4.0) provides innovations, new tools and technologies for industries. These can be used to optimize industries' relationship with water management through smart production and connected manufacturing.[25] A case history of water savings resulting from using the Internet of Things (IoT) is described in Box 4.3.

4.2.8 Ecosystem services

The extent to which industry can limit its demands and effects on ecosystem services (see Chapter 6) will have direct repercussions on the prosperity of others. Water resources – supply and quality – are a major component of natural capital; accounting for its use in business operations can highlight impacts and promote better investments. The Natural Capital Protocol is *"a decision-making framework that enables organizations to identify, measure and value their direct and indirect impacts and dependencies on natural capital"* (Capitals Coalition, n.d.). Nature-based solutions go hand in hand with natural capital and are often used in combination with grey infrastructure. Constructed wetlands are a well-known application that serves to treat certain types of industrial wastewater. They are known for low operation costs related to their long-term performance and low maintenance (Public Services and Procurement Canada, 2019).

4.2.9 Laws, regulations and guidelines

Industry's ability to leverage water for prosperity is additionally affected, both positively and negatively, by factors beyond its control. Policies and regulations are significant drivers, often based on financial incentives or command-and-control approaches (i.e. 'carrot and stick').

Direct measures may include penalties and fines or tax breaks, and decisions need to be made about targeting prevention or treating pollution. Gauging their effectiveness is difficult and depends on the country and specific circumstances, as well as on good data and information, which are often lacking. Enforcement is sometimes very poor.

Industry guidelines are influencing how companies respond to water issues in broader respects. For example, the Standard for Responsible Mining by the Initiative for Responsible Mining Assurance (IRMA) includes a section on water management (IRMA, 2018).

4.3 Industry, water and peace

Where there is violent conflict or war, industry may be targeted, resulting in workers being injured or killed, and facilities and plants damaged or destroyed. These are events essentially beyond the control of industry. However, in terms of local disputes and confrontations over water, for example in mining, industry may be viewed as a perpetrator; yet on the other side of the coin, it can lower tensions by leveraging its influence over the use of water through partnerships and cooperation. In these instances, company reputations can be a stake.

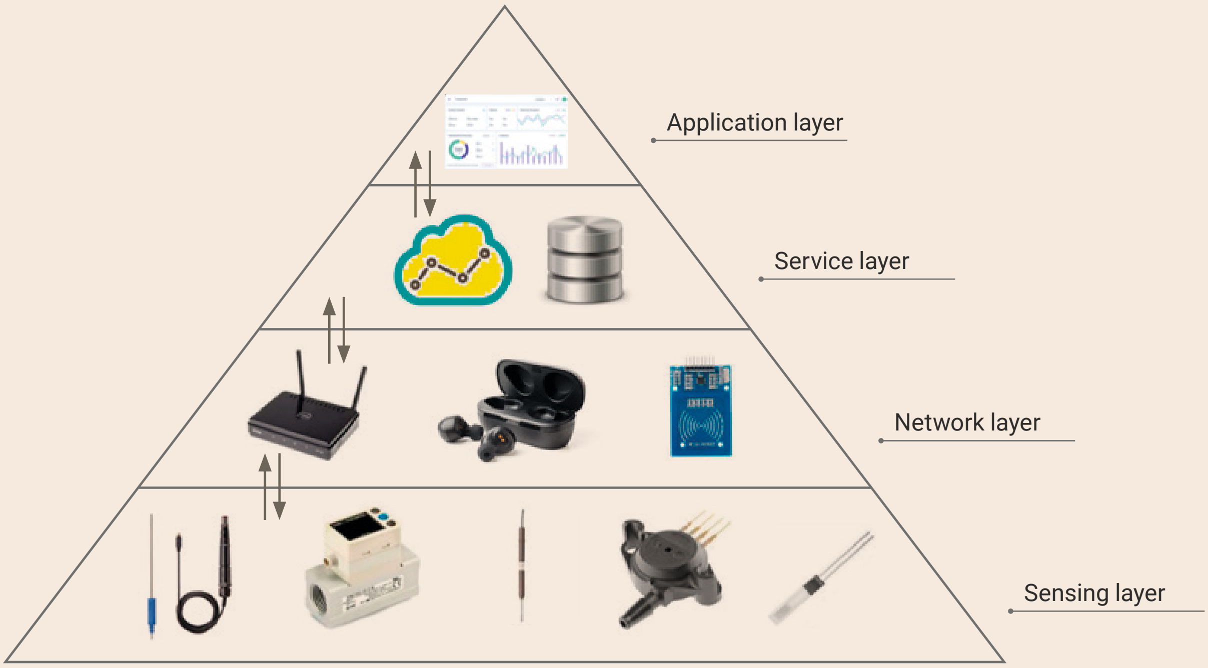
Water scarcity or pollution frequently drives such confrontational situations where several parties, including industry, require water from limited supplies, leading to competition between unequal parties.

Mining appears to be especially prone to disputes over water, especially in remote regions and in contexts involving indigenous populations (Box 4.4). A study of 384 cases of conflicts over water involving indigenous peoples found that two-thirds were caused by mining and hydropower projects (each at 31% of the total). Nearly half of the events were in Latin America and the Caribbean. Of the total 384 events, 48% identified mining as being responsible for deterioration of water quality and water availability. Significant violence occurred at some

[25] Connected manufacturing uses cloud computing of operational and business data to improve processes.

Box 4.3 Using Internet of Things (IoT) for water efficiency

An IoT-based real-time water monitoring system was implemented in a food beverage factory to analyse the complete water usage, to devise solutions, and to address water overconsumption/wastage during the manufacturing process. The IoT architecture allowed continuous monitoring of water consumption using four layers, as shown in the diagram. The data processing was carried out in a cloud system. Sensors monitored the quality of the water and wastewater, and flow rate meters measured water consumption.



The system had features such as monitoring, controlling and regulating the consumption and quality of water. Other functionalities included diverting wastewater from certain food production processes to serve as a raw material in other secondary processes (depending on its quality), rather than sending the wastewater to the effluent treatment plant. This water monitoring system provided detailed insights into the water usage of the beverage factory (value stream mapping) and thus informed activities to improve the quality of water, increase the efficiency of water processing systems, control water leakages, and optimize water consumption. Most water was found to go to the finished beverages, but major water consumption was also noted in the cooling towers, boiler and bottle washers. Water saving initiatives were:

- **Cascade reuse** – Washing of dirty bottles in a counter-current flow of water.
- **Taps/pipes leakages** – Fixing of identified leakages.
- **Cooling tower** – Recirculation of cooling water; exploring the reuse of cooling water as feedwater or make-up water for other processes.
- **Cleaning in place (CIP)** – Exploring newer CIP technologies such as whirlwind/ozone/electrochemically active technology with better water use reduction opportunities.

The volume of water to produce 1L of product was reduced from 2.49L to 1.9L, and the daily water usage of the factory was reduced by approximately 11%.

Source: Adapted from Jagtap et al. (2021).

point in nearly two thirds of the cases. Formal cooperative agreements were reached in only 3% of the cases, and a third of the projects had to be cancelled or renegotiated (Jiménez et al., 2015).

4.4 Conclusions

Techniques and technology that increase water efficiency and minimize use are generally not difficult to implement, but sometimes they are expensive. Complementary to these are motivation; drivers such as cost savings, regulations, and climate change; the circular economy; plus both political will and citizen support. Long-term planning and horizon scanning should prevail over short-term returns. Industry has the adaptive capacity and the advantage of agility and proactiveness to move quickly to effect changes. These changes are increasingly necessary in the context of stewardship to support sustainable prosperity (Debaere et al., 2015). The Alliance for Water Stewardship, a collaboration between businesses, non-governmental organizations (NGOs) and the public sector, has a global standard for water stewardship (AWS, n.d.). The UN Global Compact promotes water sustainability through The Water Resilience Coalition and its Net Positive Water Impact (NPWI) initiative to ensure a *"company's contributions exceed impacts on water stress in the same region"* (UN Global Compact, n.d.).

Over twenty years ago, two paths to address the distribution, management and use of water were put forward in a prescient article (Gleick, 2002, p. 373). The 'hard path' uses *"centralized infrastructure to capture, treat and deliver water supplies"* and the 'soft path' complements this *"by investing in decentralized facilities, efficient technologies and policies, and human capital."* The soft path requires collaboration and includes private companies. It aims to increase water productivity rather than supply, and sever the ties between water and economic growth. Its call for action by many individual users, including industry, remains relevant today.

Box 4.4 Examples of disputes over water involving the mining industry in Latin America

In Chile, violent protests over water use that killed three people stopped the Tía María US$1 billion copper mining project in 2011.

In Peru, the projected Minas Conga open pit mine (extending the large Minera Yanacocha gold mine) would affect the people living in Cajamarca, who relied on access to groundwater from alpine lakes for agriculture. Moreover, pollution of the water from the Minera Yanacocha mine was a significant issue. After the government approved the environmental impacts assessment for Minas Conga, the community continuously protested against increasing environmental impacts. The government declared a state of emergency and, in one protest in 2012, tear gas and bullets injured 20 and killed 3 people. Continuing tension and unrest led to the closure of the project in 2016.

The El Mauro tailings dam in Chile is the largest in Latin America. The local indigenous Caimanes community protested because of environmental concerns, using lawsuits, a long hunger strike and road blockages. The court ordered the dam's demolition. Negotiations attempted between the mining company and the community initially met with little progress but in 2016, after more than 10 years, an agreement was reached. This involved a desalination plant to resolve water quality issues, and resettlement compensation and land lease agreements.

Source: CDP (2022) and Oh et al. (2023).

References

AFED (Arab Forum for Environment and Development). 2010. *Arab Environment – Water: Sustainable Management of a Scarce Resource*. 2010 Report of the Arab Forum for Environment and Development. www.afedonline.org/en/reports/details/water.

_____. 2014. *Water Efficiency Handbook: Identifying Opportunities to Increase Water Use Efficiency in Industry, Buildings, and Agriculture in the Arab Countries*. A product of AFED's Arab Green Economy Initiative (AGEI). www.afedonline.org/en/publications/details/water-efficiency-handbook.

AQUASTAT. n.d. AQUASTAT FAO's Global Information System on Water and Agriculture: Water Use. FAO website. www.fao.org/aquastat/en/overview/methodology/water-use. (Accessed on 13 November 2023).

AWS (Alliance for Water Stewardship). n.d. The AWS International Water Stewardship Standard. AWS website. https://a4ws.org/the-aws-standard-2-0/. (Accessed on 13 November 2023).

Bernick, L. 2017. Why Companies and Investors Need to Value Water Differently. S&P Dow Jones Indices website, 17 March 2017. www.indexologyblog.com/2017/03/17/why-companies-and-investors-need-to-value-water-differently/.

Bryan, A., Hundertmark, T., Lueck, K., Roen, W., Siccardo, G., Tai, H. and Morrison, J. 2021. Managing Water and Climate Risk with Renewable Energy. McKinsey & Company website, 22 October 2021. https://www.mckinsey.com/industries/electric-power-and-natural-gas/our-insights/managing-water-and-climate-risk-with-renewable-energy.

Capitals Coalition. n.d. Natural Capital Protocol. https://capitalscoalition.org/capitals-approach/natural-capital-protocol/?fwp_filter_tabs=guide_supplement. (Accessed on 13 November 2023).

CDP (formerly the Carbon Disclosure Project). 2018. *Treading Water: Corporate Responses to Rising Water Challenges*. CDP Global Water Report 2018. London, CDP Worldwide. www.cdp.net/en/research/global-reports/global-water-report-2018.

_____. 2020. *Cleaning Up Their Act: Are Companies Responding to the Risks and Opportunities posed by Water Pollution?* CDP Global Water Report 2019. London, CDP Worldwide. www.cdp.net/en/research/global-reports/cleaning-up-their-act.

_____. 2021. *A Wave of Change: The Role of Companies in Building a Water-Secure World*. CDP Global Water Report 2020. London, CDP Worldwide. www.cdp.net/en/research/global-reports/global-water-report-2020.

_____. 2022. *High and Dry: How Water Issues are Stranding Assets*. A report commissioned by the Swiss Federal Office for the Environment (FOEN). London, CDP Worldwide. www.cdp.net/en/research/global-reports/high-and-dry-how-water-issues-are-stranding-assets.

Ceres. 2022. *Global Assessment of Private Sector Impacts on Water.* www.ceres.org/resources/reports/global-assessment-private-sector-impacts-water.

Damania, R., Desbureaux, S., Hyland, M., Islam, A., Moore, S., Rodella, A.-S., Russ, J. and Zaveri, E. 2017. *Uncharted Waters: The New Economics of Water Scarcity and Variability.* Washington, World Bank. openknowledge.worldbank.org/handle/10986/28096. Licence: CC BY 3.0 IGO.

Damania, R., Desbureaux, S., Rodella, A.-S., Russ, J. and Zaveri, E. 2019. *Quality Unknown: The Invisible Water Crisis*. Washington, World Bank. openknowledge.worldbank.org/handle/10986/32245. Licence: CC BY 3.0 IGO.

Debaere, P., Karres, N. and Vigerstol, K. . 2015. *Water Stewardship for Sustainable Prosperity*. The Nature Conservancy (TNC). www.darden.virginia.edu/sites/default/files/inline-files/DebaereWaterandProsperity_TNC.pdf.

Domenech, T. and Davies, M. 2011. Structure and morphology of industrial symbiosis networks: The case of Kalundborg. *Procedia – Social and Behavioral Sciences*, Vol. 10, pp. 79–89. doi.org/10.1016/j.sbspro.2011.01.011.

Gleick, P. H. 2002. Water management: Soft water paths. *Nature*, Vol. 418, p. 373. pacinst.org/publication/water-management-soft-water-paths/.

IEA (International Energy Agency). 2016. *Water–Energy Nexus, Excerpt from the World Energy Outlook 2016*. Paris, OECD/IEA. www.iea.org/reports/water-energy-nexus.

IRMA (Initiative for Responsible Mining Assurance). 2018. IRMA Standard for Responsible Mining IRMA-STD-001. IRMA. https://responsiblemining.net/resources/#full-documentation-and-guidance.

Jagtap, S., Skouteris, G., Choudhari, V., Rahimifard, S., Duong, L. N. K. 2021. An Internet of Things approach for water efficiency: A case study of the beverage factory. *Sustainability*, Vol. 13, No. 6, Article 3343. doi.org/10.3390/su13063343.

Jiménez, A., Molina, M. F. and Le Deunff, H. 2015. Indigenous peoples and industry water users: Mapping the conflicts worldwide. *Aquatic Procedia*, Vol. 5, pp. 69–80. doi.org/10.1016/j.aqpro.2015.10.009.

McKinsey & Company. 2009. *The Global Corporate Water Footprint: Risks, Opportunities, and Management Options*. www.mckinsey.com/~/media/mckinsey/dotcom/client_service/sustainability/pdfs/report_large_water_users.aspx.

NRDC (Natural Resources Defense Council). 2016. Encourage Textile Manufacturers to Reduce Pollution. NRDC website, 21 January 2016. www.nrdc.org/issues/encourage-textile-manufacturers-reduce-pollution.

Oh, C. H., Shin, J. and Ho, S. S. H. 2023. Conflicts between mining companies and communities: Institutional environments and conflict resolution approaches. *Business Ethics, the Environment & Responsibility*, Vol. 32, No. 2, pp. 638–656. doi.org/10.1111/beer.12522.

Public Services and Procurement Canada. 2019. Fact Sheet: Constructed Wetlands. Government of Canada website. https://gost.tpsgc-pwgsc.gc.ca/tfs.aspx?ID=32&lang=eng. (Accessed on 13 November 2023).

Ritchie, H. and Roser, M. 2017. Water Use and Stress. Our World in Data website. ourworldindata.org/water-use-stress#licence.

Sadoff, C. W., Hall, J. W., Grey, D., Aerts, J. C. J. H., Ait-Kadi, M., Brown, C., Cox, A., Dadson, S., Garrick, D., Kelman, J., McCornick, P., Ringler, C., Rosegrant, M., Whittington, D. and Wiberg, D. 2015. *Securing Water, Sustaining Growth*. Report of the GWP/OECD Task Force on Water Security and Sustainable Growth. Oxford, UK, University of Oxford. www.gwp.org/globalassets/global/about-gwp/publications/the-global-dialogue/securing-water-sustaining-growth.pdf.

_____. n.d. Corporate Water Use. Conservation Gateway website. www.conservationgateway.org/ConservationPractices/Freshwater/CorporateWaterUse/Pages/corporate-water-use.aspx. (Accessed on 13 November 2023).

UN Global Compact. n.d. NPWI (Net Positive Water Impact). UN Global Compact website. ceowatermandate.org/resilience/net-positive-water-impact/. (Accessed on 13 November 2023).

UNEP (United Nations Environment Programme). 2015a. *Options for Decoupling Economic Growth from Water Use and Water Pollution*. Summary for Policy Makers. https://wedocs.unep.org/handle/20.500.11822/7539.

_____. 2015b. *Options for Decoupling Economic Growth from Water Use and Water Pollution*. A report of the Water Working Group of the International Resource Panel. www.resourcepanel.org/reports/options-decoupling-economic-growth-water-use-and-water-pollution.

_____. 2018. Putting the Brakes on Fast Fashion. UNEP website, 12 November 2018. www.unenvironment.org/news-and-stories/story/putting-brakes-fast-fashion.

UNIDO (United Nations Industrial Development Organization). 2019. *Eco-Industrial Parks: Achievements and Key Insights from the Global RECP Programme 2012–2018*. Vienna, UNIDO. www.unido.org/sites/default/files/files/2019-02/UNIDO_EIP_Achievements_Publication_Final.pdf.

UNIDO/World Bank Group/GIZ (United Nations Industrial Development Organization/World Bank Group/Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH). 2021. *An International Framework for Eco-Industrial Parks: Version 2.0.* Washington, World Bank. openknowledge.worldbank.org/handle/10986/35110.

United Nations. 2023. *The United Nations World Water Development Report 2023: Partnerships and Cooperation for Water*. Paris, United Nations Educational, Scientific and Cultural Organization (UNESCO). unesdoc.unesco.org/ark:/48223/pf0000384655?posInSet=1&queryId=524e3791-3f6b-402d-be29-6ª436f0d39bd.

Water Footprint Network. n.d. Do you know how much water was used to grow your food and to produce your clothes and the things you buy? Water Footprint Network website. www.waterfootprint.org/time-for-action/what-can-consumers-do/#product. (Accessed on 13 November 2023).

Water Technology. 2013. BHP and Rio Tinto to Invest $3bn in Water Desalination Plant for Escondida Mine. Water Technology website, 28 July 2013. www.water-technology.net/uncategorised/newsbhp-rio-tinto-to-jointly-invest-3bn-in-water-desalination-plant-for-escondida-mine/.

Weiss, F. T., Leuzinger, M., Zurbrügg C., Eggen, R. I. L. 2016. *Chemical Pollution in Low- and Middle-Income Countries*. Swiss Federal Institute of Aquatic Science and Technology (Eawag). www.eawag.ch/fileadmin/Domain1/Abteilungen/sandec/publikationen/Chemical_Pollution/Lamics-WEB.pdf.

WWAP (UNESCO World Water Assessment Programme). 2017. *The United Nations World Water Development Report 2017. Wastewater: The Untapped Resource*. Paris, United Nations Educational, Scientific and Cultural Organization (UNESCO). unesdoc.unesco.org/ark:/48223/pf0000247153?posInSet=1&queryId=05d498d9-6675-4460-9884-55155a9ed7ae.

Zhou, Q., Yang, N., Li, Y., Ren, B., Ding, X., Bian, H., Yao, X. 2020. Total concentrations and sources of heavy metal pollution in global river and lake water bodies from 1972 to 2017. *Global Ecology Conservation*, Vol. 22, Article e00925. doi.org/10.1016/j.gecco.2020.e00925.

Chapter 5

Energy

UNIDO

John Payne

WWAP

Richard Connor and Simón Matius Chaves Pacheco

Water plays an important role in all aspects of energy production. In terms of primary energy (i.e. fuels), water is required in the extraction and conversion processes of coal, oil and gas (including fracking). It is also extensively used for electricity generation, in hydropower and as cooling water for thermal and nuclear power stations. Additional water uses for energy production include crop irrigation for biofuels and the manufacturing of equipment for renewables, such as solar panels and wind turbines.

Achieving universal coverage for both drinking water and electricity involves reducing energy's dependence on water and vice versa

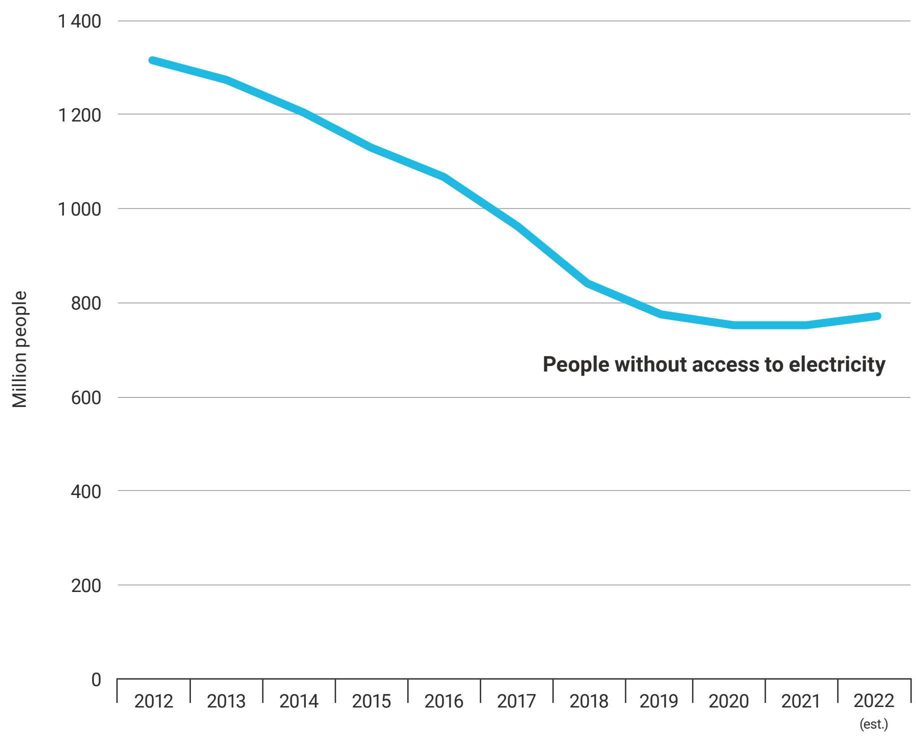
Achieving Sustainable Development Goal (SDG) 7 – ensuring access to affordable, reliable, sustainable and modern energy for all – will require an acceleration in the uptake of renewable energy (IEA/IRENA/UNSD/World Bank/WHO, 2023). The challenge is to adopt types of renewable energy that also have a low water intensity.

The other side of this connection is that considerable amounts of energy are used to pump, treat and transport water and wastewater, including for irrigation and industry. Achieving universal coverage for both drinking water and electricity involves reducing energy's dependence on water and vice versa, with a view towards lowering greenhouse gas (GHG) emissions.

While the number of people without access to electricity has dropped by roughly 500 million over the past decade (Figure 5.1), progress began to stagnate around 2019 (IEA, 2022a). In 2021, an estimated 675 million people still lacked access to electricity, of whom 567 million lived in Sub-Saharan Africa. These numbers are somewhat similar to those for people without a basic water supply service (703 million), without a handwashing facility (653 million), and who practice open defecation (419 million) (United Nations, 2023).

When electricity is made available, it allows for the pumping, treatment and distribution of water required for improved water supply, sanitation and hygiene (WASH) services. Access to electricity also decrease the use of biomass for cooking,[26] which contributes to

Figure 5.1
People without access to electricity worldwide, 2012–2022



Source: IEA (2022a). Licence CC BY 4.0.

[26] *"In 2021, around 2.3 billion people relied on inefficient and polluting cooking systems, jeopardizing their health, limiting their life opportunities, and damaging the climate and environment"* (United Nations, 2023, p. 26).

improved health outcomes. As reported in the *United Nations World Water Development Report 2014* on water and energy, *"the fact that these figures are often representative of the same people is evidenced by a close association between respiratory diseases caused by indoor air pollution, and diarrhoea and related waterborne diseases caused by a lack of safe drinking water and sanitation"* (WWAP, 2014, p. 2).

By potentially freeing up large quantities of water, the energy sector will have a great influence on the fulfilment of SDGs 6 and 7 and the consequent well-being and prosperity of many who suffer from a lack of water supply and sanitation services, while at the same time providing more power to those who desperately need it the most.

5.1 Water for energy

The amounts of water required to generate fuels and electricity vary considerably based on the resources used, the extraction and conversion process, and the overall amount of energy they create. There are two distinct categories of water use. Water withdrawal refers to the volume derived from a source (lake, river, aquifer, etc.) and returned to the environment after use. Water consumption corresponds to the amount permanently removed from its source.

The quantity of water ***withdrawn*** for energy production (Figure 5.2) is roughly ten times the volume ***consumed*** (Figure 5.3). While electricity generation (thermal and nuclear power cooling) accounts for the vast majority of withdrawals, primary energy production (fossil fuels and biofuels) is predominantly responsible for water consumption. The data suggest that water use for all types of energy production have been increasing more or less proportionally, with the exception of a notable decrease for fossil fuel-based electricity generation between 2010 and 2016, attributable to a sharp (nearly 20%) decline in coal production over that period (IEA, 2021a).[27] These graphs do not show values for hydroelectricity, which requires large volumes of water, both in terms of discharge and reservoir storage.

By potentially freeing up large quantities of water, the energy sector will have a great influence on the fulfilment of SDGs 6 and 7

The large amount of water that goes into producing both primary energy and electricity reportedly accounted for 10% of global withdrawals in 2014 (IEA, 2016, Figure 9.1, p. 352). However, based on the data reported by the International Energy Agency (IEA), water withdrawals for energy were 54.1 billion m³ in 2021 (IEA, 2023), accounting for 14% of the total 3,900 billion m³ withdrawals in 2020 (World Bank, n.d.). This would account for a considerable proportion of the water use attributed to the industry sector (17% of the total amount – see section 4.2.2), which includes energy. This uncertainty notwithstanding, in terms of electricity generation, the most water-efficient sources are wind and solar-photovoltaic (PV) (WWAP, 2014).

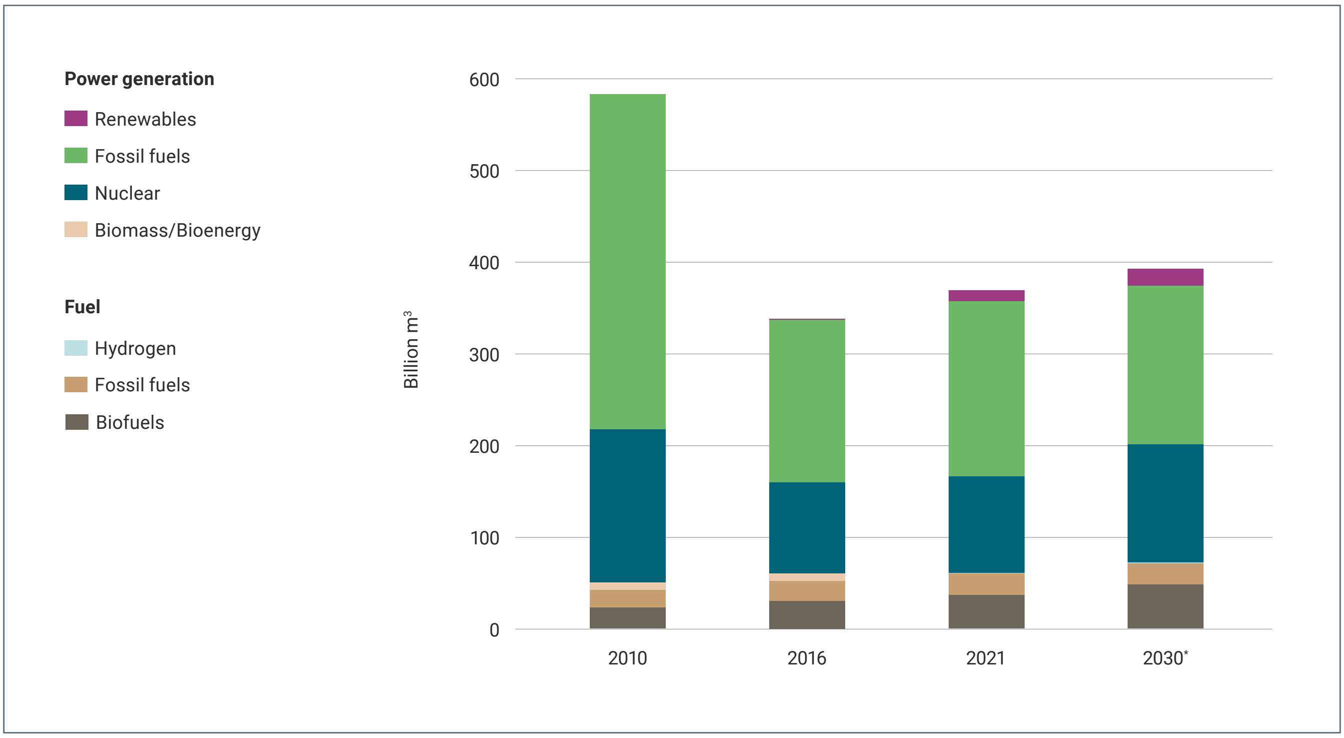
According to Figure 5.4, significant progress has been achieved between 2011 and 2019,[28] as the proportion of solar and wind in the global power generation mix rose from 0.3% to 2.6%, and from 2.0% to 5.3%, respectively. However, meeting SDG 7 will require a substantial increase in the share of renewable energy sources for electricity (in addition to transport and heat) (IEA/IRENA/UNSD/World Bank/WHO, 2023). Such progress would also directly help achieving SDG 6, especially in areas facing water scarcity or where competition over finite resources between water use sectors could undermine prosperity.

---

27 Between 2010 and 2016, water withdrawal and consumption for coal-fired powerplants reportedly dropped from 335 billion m³ to 150 billion m³ and from 38 billion m³ to 8 billion m³, respectively (IEA, 2012; 2020a).

28 These dates were chosen to compare the most recent data (2019) available (IEA, 2023) with the 2011 data presented in the *United Nations World Water Development Report* (WWAP, 2014).

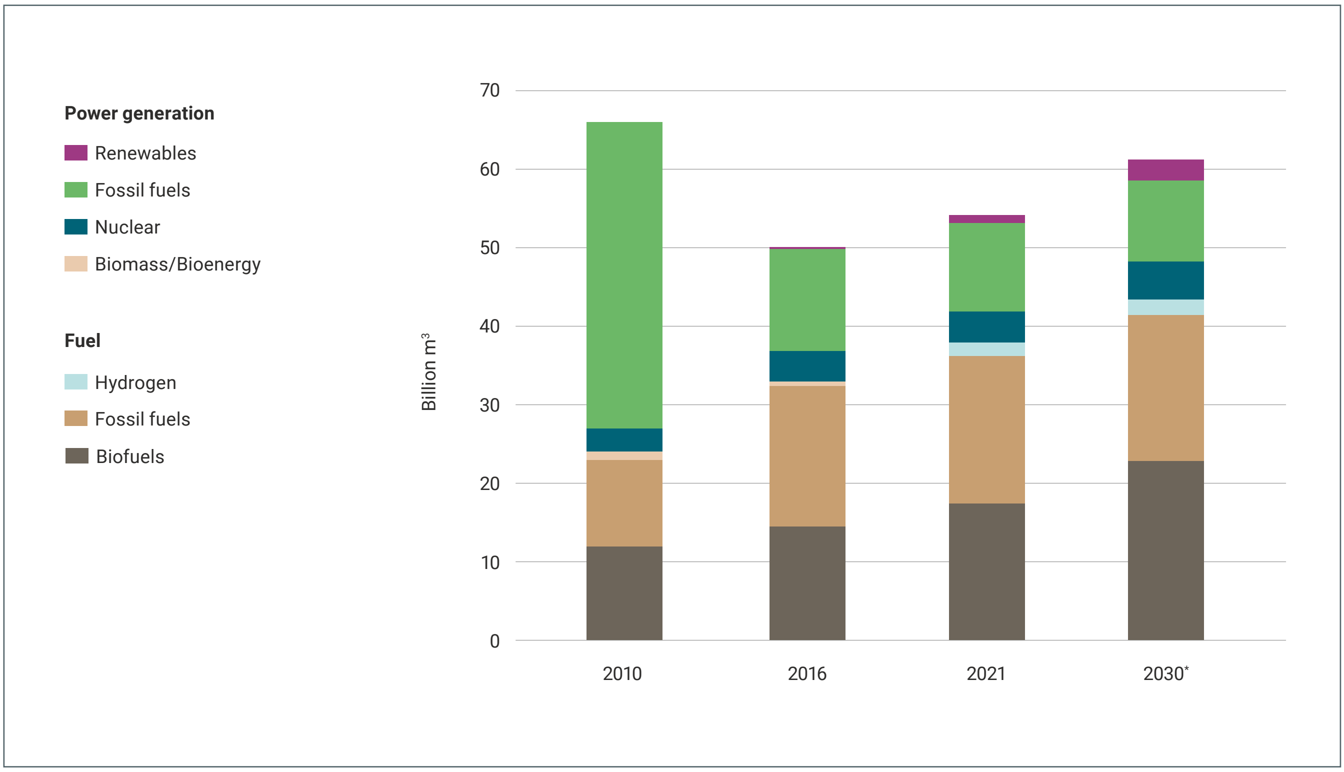
Figure 5.2 Global energy sector: Water withdrawal by fuel and power generation type



* Estimate based on most conservative scenario

Source: Authors, based on data from IEA (2012) for 2010, IEA (2020a) for 2016, and IEA (2023) for 2021 and 2030. Licence CC BY 4.0.

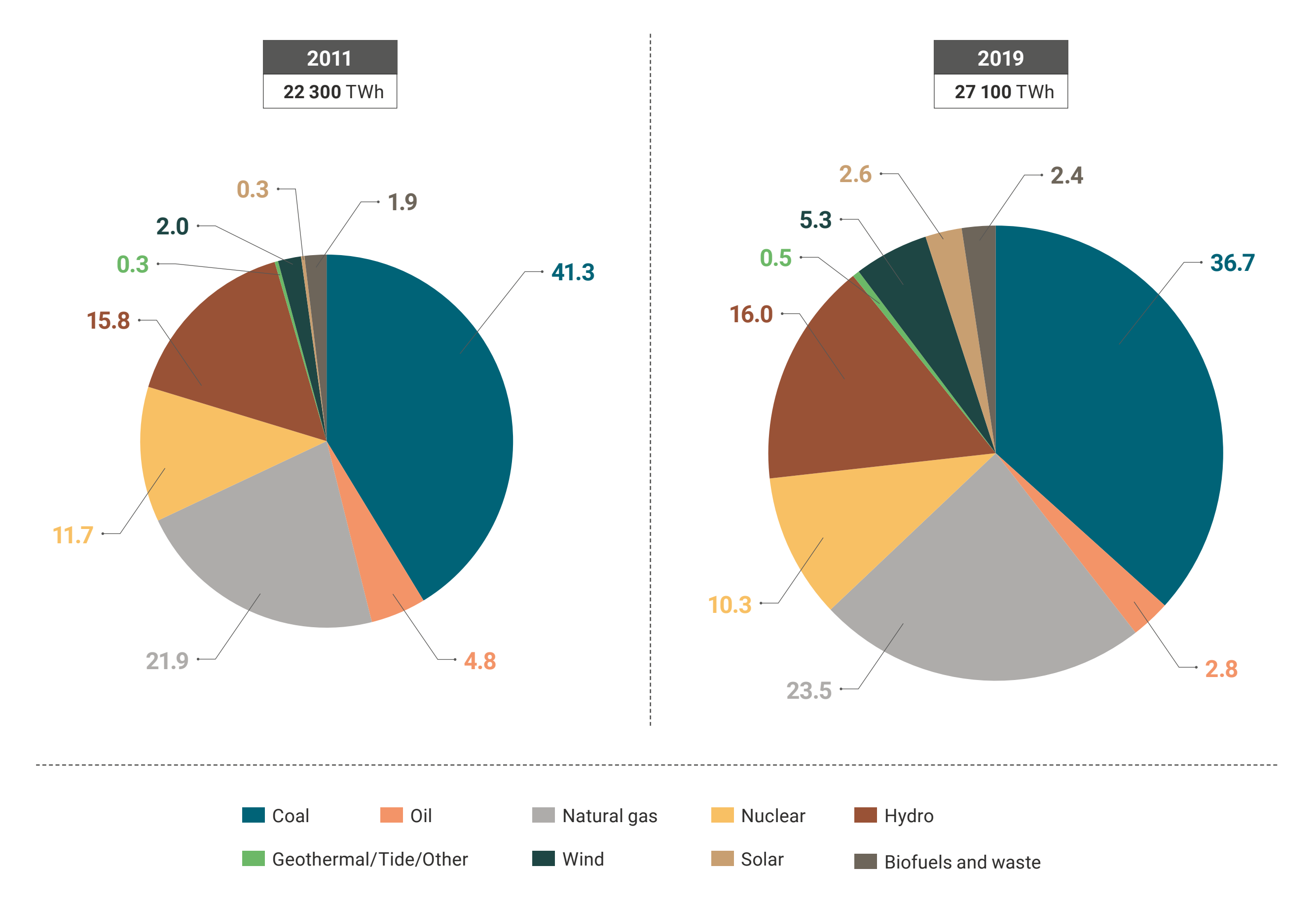
Figure 5.3 Global energy sector: Water consumption by fuel and power generation type



* Estimate based on most conservative scenario

Source: Authors, based on data from IEA (2012) for 2010, IEA (2020b) for 2016, and IEA (2023) for 2021 and 2030. Licence CC BY 4.0.

Figure 5.4 World electricity generation by source (%)



Source: Authors, based on data from IEA (2021b) for 2011, and IEA (2019) for 2019. Licence CC BY 4.0.

In terms of electricity generation, the most water-efficient sources are wind and solar-photovoltaic

5.1.1 Renewables

Some renewables have little or no impact on water use, or even mitigate water depletion, while others require large quantities of water. The choice of which renewable technology to deploy also depends on many other factors – technical, social, economic, and environmental – besides water stress (availability, quality, accessibility). Utility-scale solar PV and onshore wind are the fastest-growing renewables (Wiatros-Motyka, 2023) and "*the cheapest options for new electricity generation in a significant majority of countries*" worldwide (IEA, 2022b).

Globally, ***solar PV*** represented over 40% of investment in electricity generation in 2022, three times the spending on all fossil fuel technologies collectively (IEA, n.d.). Solar PV only requires small amounts of water, for manufacturing and cleaning panels (Stolz et al., 2017). However, it also has the potential to mitigate water loss with other co-benefits when the panels are installed over water (Box 5.1). By contrast, ***concentrated solar power*** (CSP) requires substantial amounts of cooling water, presenting difficulties in the hot and arid climates where CSP works best. Dry (air) cooling is an alternative but reduces efficiency and increases costs, whereas hybrid wet/dry cooling could produce a 50% decrease in water consumption with a minimal loss in efficiency (IEA, 2010).

Wind power has little direct interaction with freshwater (though historically there was an energy nexus as windmills were constructed to pump water). Currently the main water relationship is with saltwater, as many wind farms are constructed offshore. Onshore wind farms can lead to land use conflicts and are sometimes perceived as aesthetically disturbing. Both have ecosystem interactions with wildlife and noise.

Box 5.1 **Solar canals: Innovation in the energy–water nexus**

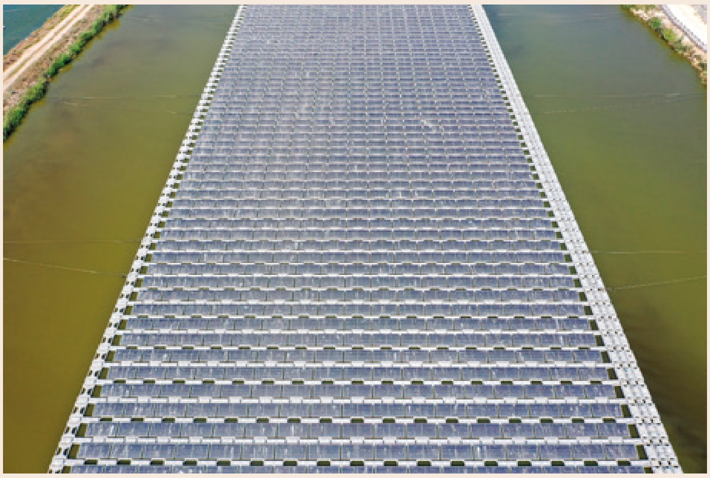


*Photo: © Shutterstock/StockStudio Aerials**

Almost ten years ago, a pilot project in Gujarat (India) put solar panels over canals, saving valuable land. There were multiple benefits – evaporation was reduced by shading so that water was saved for other uses, the water cooled the panels and made them more efficient, and the shade reduced algal blooms. One estimate suggested that 2 to 3 MW could be generated per kilometre (Gupta, 2021). A study in California suggested that enough water could be saved for 2 million people if all the 6,400 km of open canals were covered with solar panels, which themselves would generate 13 GW of renewable power (Anderson and Hendricks, 2022). Floating solar panels covering reservoirs could yield similar benefits (Jin et al., 2023), which include hindering weed growth and minimizing land use for new solar installations.

Pumped-storage hydropower (PSH) can provide energy-balancing, stability, storage capacity and ancillary grid services, such as network frequency control and reserves

Given the tremendous growth in solar PV and wind power, it is very fortunate that both technologies have positive impacts in terms of water use for power generation. This improvement, combined with their essentially local deployment, can yield a win–win situation for both power and water, promoting community-level prosperity.

Hydropower accounts for 16% of global power generation (Figure 5.4) and its growth has been keeping pace with total electricity production. The economic, social and environmental 'pros' and 'cons' of hydropower have been well established for decades (see for example WWAP, 2003), but they can vary considerably depending on the specific type of project and its location. However, with proper design and regular maintenance, hydropower facilities can remain operational for over 100 years (IHA, 2023). ***Pumped-storage hydropower*** (PSH) can provide energy-balancing, stability, storage capacity and ancillary grid services, such as network frequency control and reserves. The rate of energy loss from PSH has been estimated at around 20% (ESA, n.d.). Its cost-effectiveness compares well with other forms of energy storage, especially for very large capacity storage (IHA, 2023).

Geothermal energy production systems are long-lasting and consume very little water, approximately 70 times less per MWh than natural gas generation (Kagel et al., 2007), yet they remain highly under-represented in the global power generation mix. However, in some enhanced geothermal systems that need water injections for steam, some of the water can be reused in a closed loop system, but this will result in big losses and therefore a large consumption of water relative to thermal plants (IEA, 2016). Water reinjection takes place at depth and does not come into contact with groundwater, so negative impacts on groundwater and surface water are unlikely to occur (Kagel et al., 2007).

Bioenergy generated only 2.4% of global electricity in 2022 (Wiatros-Motyka, 2023), which is the same ratio reported in 2019 (Figure 5.4). Most of the biomass used comes in the form of wood pellets from sawdust, a by-product of lumber and paper production, or it is derived from low-quality or dead trees (McDonald, 2022). They are burned in generating stations, sometimes in co-firing with coal. The generating stations are cooled in the same way as other thermal stations and therefore present a similar level of water use (EPC, n.d.).

While ***biofuels*** are not generally used to produce electricity, they do fall under the 'water for energy' category. Biofuels, such as ethanol, are mainly used in transportation in place of fossil fuels. When crops are specifically grown for biofuels, water (both withdrawn and consumed) is a major factor. The water intensity of biofuels is orders of magnitude higher than for fossil fuels. Irrigated soybean biodiesel, for example, ranges between 10^3 and 10^6 litres per toe (tonne of oil equivalent), whereas conventional oil is roughly between 10^2 and 10^4 litres per toe (IEA, 2016, Figure 9.4, p. 358). Water quality is also a factor, as runoff can carry fertilizers and pesticides (WWAP, 2017). Additional concerns include their effects on food prices, the risk of increase in GHG emissions through direct and indirect land use change (LUC), as well as the risks of degradation of land, forests, water resources and ecosystems (UNEP/IRP, 2009). This raises concerns about the overall sustainability of irrigated crop biofuels in some geographies, indicating that they may not necessarily be conducive to prosperity and economic well-being for all.

Desalination is very energy-intensive, accounting for 26% of the energy in the water sector globally

Nuclear power[29] uses roughly the same water per unit of energy (perhaps a bit more) than similar cooling systems in coal and natural gas plants (IEA, 2016). Once-through cooling is common and the increased discharge water temperature can have detrimental environmental effects. The use of nuclear power is often pre-empted by concerns over safety, costs and waste disposal, rather than water.

Small Modular Reactors (SMRs) that are easily transported, especially to remote areas, are gaining attention. They have a self-contained design and cooling water is used in a continuous loop. Some designs do not use any water but other types of coolant. The intention is to put SMRs underground, but this raises concerns regarding groundwater contamination (McDonald, 2022).

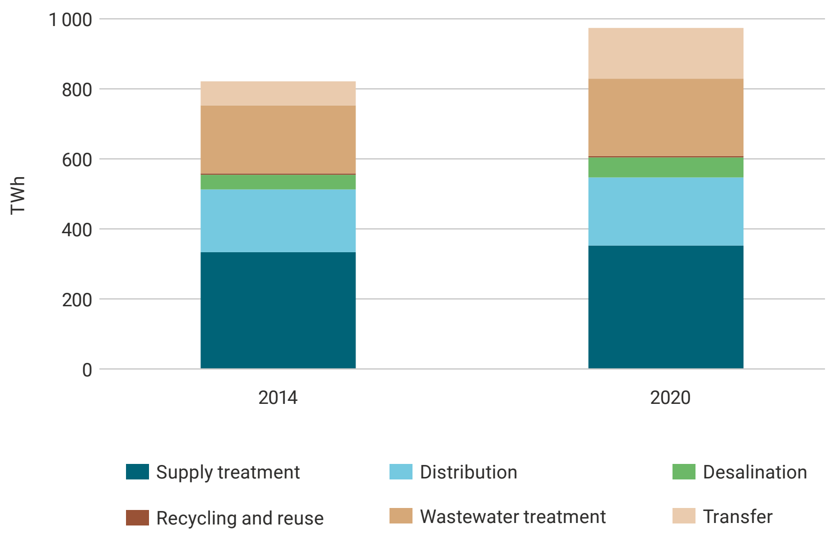
5.2 Energy for water

The total amount of energy (mainly electricity) used to manage and manipulate water – from abstraction through pumping and distribution, to treatment for use and disposal – is difficult to accurately assess (WWAP, 2017). In 2020, it was estimated at just under 1,000 TWh. For context, global electricity demand in 2021 was 24,700 TWh (IEA, 2022c). It can thus be deduced that water currently accounts for roughly 4% of the equivalent global electricity demand. Figure 5.5 provides a general picture of the electricity intensity of water subsectors.

The IEA (2020c) has predicted large increases in energy demand for desalination, large-scale water transfers and more wastewater treatment (both in terms of the volume and the intensity of treatment) through 2040. ***Water reuse*** offers one of the most promising approaches to sustainably meet the growing demand for water (WWAP, 2017), but it is currently so sparsely applied that its application would need to increase by nearly two orders of magnitude before matching the energy demand of the processes mentioned above.

[29] Whether categorized as 'renewable' or not, nuclear power provides a source of low-carbon electricity and heat.

Figure 5.5
Total electricity consumption by water management process, 2014–2020



Source: IEA (2020c). Licence CC BY 4.0.

Desalination is very energy-intensive, accounting for 26% of the energy in the water sector globally (IEA, 2018). In 2018, there were about 16,000 operational desalination plants, of which about half of the total production is located in the Middle East and North Africa region. The municipal sector is the largest user of desalinated water in terms of capacity (62%), followed by industry (30%) (Jones et al., 2019). Since desalination plants generate GHG emissions when their power supply is based on fossil fuels, plants powered by renewables are much more desirable. Hence solar PV and wind power may come into play, with the bonus that they are suited to hot dry climates, which are the ones most likely to suffer from water shortages. An example is a partnership in Kenya providing solar-powered desalinated water to 23 local hospitals (REN21, 2022). However, the environmental problems associated with desalination, like brine disposal and impacts on marine ecosystems, should not be overlooked.

5.3 The water–energy–climate change nexus

The decarbonization of energy is targeted at reducing or eliminating GHG emissions. For many, the impacts in terms of water may be a secondary consideration. However, the increasing prominence of renewables has not reduced the reliance of the energy sector on considerable volumes of water.

Climate change can directly impact energy production, notably through its effects on the variability of water supplies, particularly with respect to extreme weather triggered by climate change, and the effects of drought and flooding on water use. For example, several nuclear reactors in France had restrictions placed on their output because of high temperatures of discarded cooling water, which could harm wildlife (Crellin, 2022). Also in France, two reactors in Chooz on the Belgian border were shut down due to low water levels in the river Meuse (RFI and Woods, 2020). Drought led to very low water levels in the Rhine in 2022, which threatened the output of a coal-powered generating station near Frankfurt due to disruptions in delivering coal (Connolly, 2022).

Such oscillations in energy production can have serious repercussions on local and national economies, with transboundary implications. In 2023, a drought in Laos, and the subsequent reduction in river flow, raised concerns over the country's ability to export electricity from hydropower plants to Thailand (Apisitniran, 2023). Situations such as this generate financial risks to the exporting country, as well as energy security risks to the importing country.

The potential roles of water in mitigating GHG emissions, through practices ranging from agricultural land use through to wastewater treatment, have been highlighted in the 2020 edition of the *United Nations World Water Development Report* (UNESCO/UN-Water, 2020). ***Carbon capture and storage (CCS)*** has been proposed as an innovative technology that captures CO_2 from GHG-generating power plants (and other industrial processes such as steel and cement production) and stores it deep underground. These systems are both highly energy- and water-intensive. Not only do they require more water for cooling at the power plant level, they also require additional water as an integral part to the carbon capture processes – potentially increasing a plant's water withdrawal and consumption by as much as 90% per MWh (Global CCS Institute, 2015). According to one study, "*the widespread deployment of CCS to meet the 1.5°C climate target would almost double anthropogenic water footprint*" (Rosa et al., 2021, p. 1).

Carbon capture and storage (CCS) systems are both highly energy- and water-intensive

Decarbonizing energy will depend heavily on ***critical minerals***. For example, solar PV needs approximately six times more of these minerals, measured as kg per MW of installed power, than a natural gas plant (IEA, 2022c). Additionally, critical minerals frequently need more water and have high eco-toxicity (IEA, 2021c). A major challenge for wind and solar power is their intermittent generation, as electricity would need be stored for when the sun is not shining or the wind not blowing. While PSH shows much room for expansion (NHA, 2021), lithium-ion batteries are the fastest-growing storage technology (IEA, 2022c). However, obtaining lithium comes with impacts to water and local populations in countries such as Chile (Box 5.2).

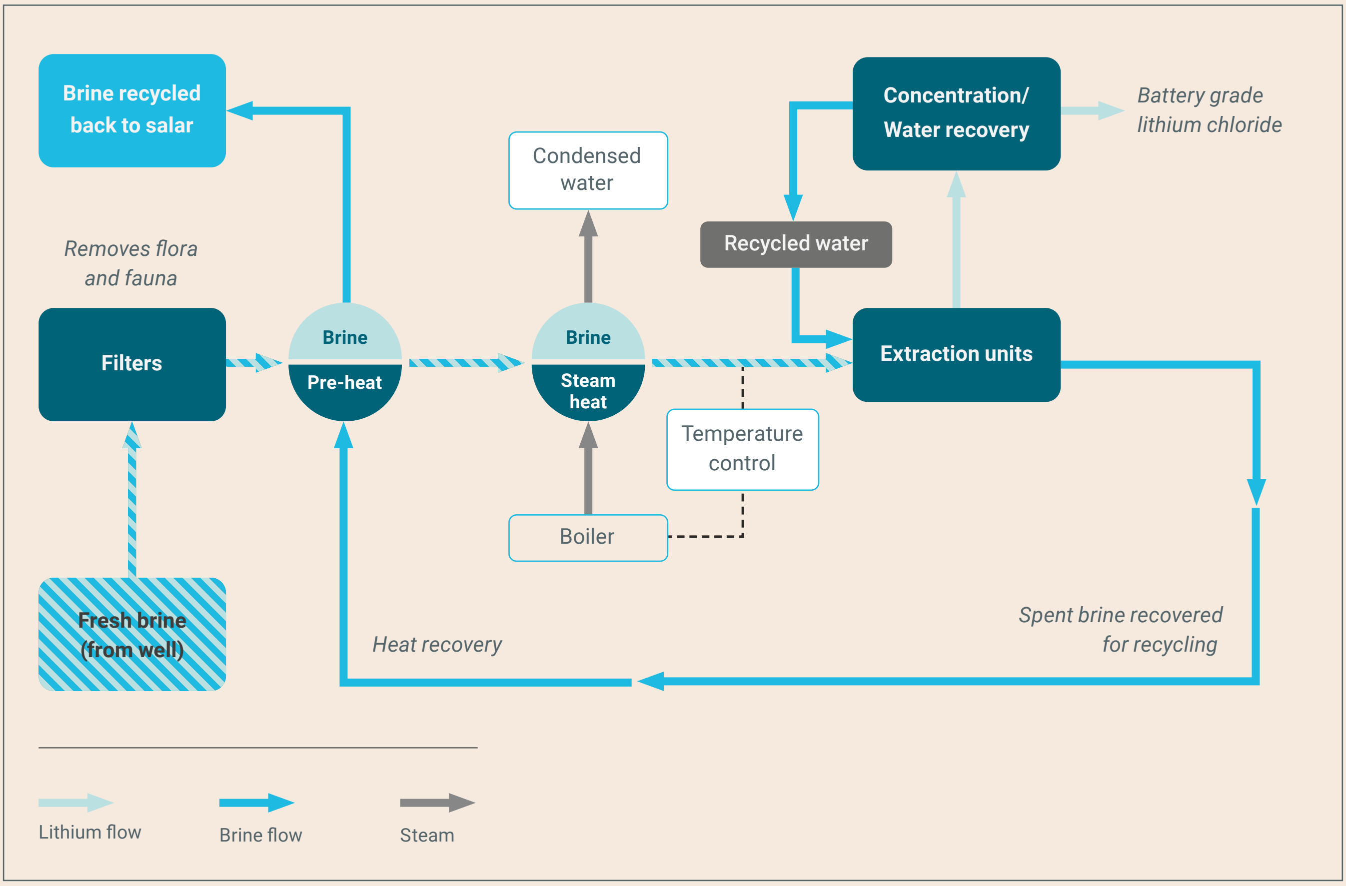
In the pursuit of net-zero, progress towards renewable energy, especially wind and solar, may have a positive effect on the energy–water nexus, though there will still be large water demands for hydro and other water-intensive energy technologies. There will also be increasing impacts on energy through water as a result of climate change, which will go hand-in-hand with increased demands for water and energy as populations increase and countries strive to meet SDGs 6 and 7. Notwithstanding, it appears that water still has a dangerously low priority on the energy spectrum. The World Energy Council's Global Issues Energy Map (WEC, 2022) suggests that land and water availability does not keep "*energy leaders awake at night*" – maybe it should…

Box 5.2 Energy storage, lithium and water

Better batteries are a key component of renewable energy, either to power vehicles (EVs) or to store electricity from intermittent sources, such as wind and solar. Currently such batteries rely on lithium, which is in high demand. Lithium is mined (in Australia) or produced from evaporation of groundwater brines, which depletes aquifers in water-stressed locations such as Chile. It is estimated that one tonne of lithium requires 2.2 million litres of water to produce (Silva and AFP, 2023). This has major impacts on groundwater and the lives of local communities, as well as on the environment. However, there is increasing interest in direct lithium extraction (DLE) from the brine in aquifers (see Figure). Instead of using evaporation ponds that do not recharge the aquifer, the brine is pumped to the surface and passed through an extraction unit, and the remaining brine is pumped back into the aquifer. The technologies are mainly at the development stage and need to become commercially viable. A similar process is being evaluated in old abandoned oil fields, such as in Canada, which are underlain by large amounts of brine with traces of lithium.

Source: Compiled from Silva and AFP (2023); Azevedo et al. (2022); Airswift (2022), CleanTech Lithium (n.d.), and Lorinc and Tuttle (2023).

Direct lithium extraction process



Source: Based on International Battery Metals (2021).

References

Airswift. 2022. Lithium Extraction Technology: The Now and Then of Rising Solutions. Airswift website, 25 August 2022. www.airswift.com/blog/lithium-extraction-technology#:~:text=The%20process%20occurs%20by%20pumping,which%20is%20very%20time%2Dconsuming.

Anderson, L. and Hendricks, J. 2022. Solar-Paneled Canals Getting a Test Run in San Joaquin Valley. UC Merced website, 8 February 2022. news.ucmerced.edu/news/2022/solar-paneled-canals-getting-test-run-san-joaquin-valley.

Apisitniran, L. 2023. Drought Limits Electricity Imports: Hydropower Plants in Laos under Pressure. Bangkok Post website, 15 August 2023. www.bangkokpost.com/business/general/2629681/drought-limits-electricity-imports?v=0630.

Azevedo, M., Baczyńska, M., Hoffman, K. and Krauze, A. 2022. Lithium Mining: How New Production Technologies could Fuel the Global EV Revolution. McKinsey & Company website, 12 April 2022. www.mckinsey.com/industries/metals-and-mining/our-insights/lithium-mining-how-new-production-technologies-could-fuel-the-global-ev-revolution#/.

CleanTech Lithium. n.d. Direct Lithium Extraction: Process Overview. CleanTech Lithium website. ctlithium.com/about/direct-lithium-extraction/.

Connolly, K. 2022. Low Water Levels mean Rhine is Days from being Shut for Cargo. The Guardian website, 5 August 2022. www.theguardian.com/world/2022/aug/05/rhine-low-water-levels-shut-cargo.

Crellin, F. 2022. Warming Rivers Threaten France's already Tight Power Supply. Reuters website, 15 July 2022. www.reuters.com/business/energy/warming-rivers-threaten-frances-already-tight-power-supply-2022-07-15/.

EPC (European Pellet Council). n.d. A Unique Biomass Fuel. EPC website. epc.bioenergyeurope.org/about-pellets/pellets-basics/%ef%bb%bf-wood-pellets-a-unique-biomass-fuel/.

ESA (Energy Storage Association). n.d. Pumped Hydroelectric Storage. ESA website. http://energystorageassociationarchive.org/why-energy-storage/technologies/pumped-hydropower/.

Global CCS Institute. 2015. How Does Carbon Capture Affect Water Consumption? Global CCS Institute website. www.globalccsinstitute.com/news-media/insights/how-does-carbon-capture-affect-water-consumption/.

Gupta, U. 2021. Solar Arrays on Canals. PV magazine website, 10 March 2021. www.pv-magazine.com/2021/03/10/solar-arrays-on-canals.

IEA (International Energy Agency). 2010. *Technology Roadmap: Concentrating Solar Power.* Paris, OECD/IEA. www.iea.org/reports/technology-roadmap-concentrating-solar-power. Licence: CC BY 4.0.

_____. 2012. *World Energy Outlook 2012*. Paris, OECD/IEA. www.iea.org/reports/world-energy-outlook-2012. Licence: CC BY 4.0.

_____. 2016. *World Energy Outlook 2016*. Paris, OECD/IEA. www.iea.org/reports/world-energy-outlook-2016. Licence: CC BY 4.0.

_____. 2018. *World Energy Outlook 2018*. Paris, OECD/IEA. www.iea.org/reports/world-energy-outlook-2018. Licence: CC BY 4.0.

_____. 2019. World Gross Electricity Production by Source, 2019. Paris, IEA. www.iea.org/data-and-statistics/charts/world-gross-electricity-production-by-source-2019. Licence: CC BY 4.0.

_____. 2020a. Global Water Withdrawal in the Energy Sector by Fuel Type in the Sustainable Development Scenario, 2016-2030. Paris, IEA. www.iea.org/data-and-statistics/charts/global-water-withdrawal-in-the-energy-sector-by-fuel-type-in-the-sustainable-development-scenario-2016-2030. Licence: CC BY 4.0.

_____. 2020b. Global Water Consumption in the Energy Sector by Fuel Type in the Sustainable Development Scenario, 2016-2030. Paris, IEA. www.iea.org/data-and-statistics/charts/global-water-consumption-in-the-energy-sector-by-fuel-type-in-the-sustainable-development-scenario-2016-2030. Licence: CC BY 4.0.

_____. 2020c. Introduction to the Water-Energy Nexus. IEA website, 23 March 2020. www.iea.org/articles/introduction-to-water-and-energy. Licence: CC BY 4.0.

_____. 2021a. Key electricity trends 2020. Paris, IEA. www.iea.org/articles/key-electricity-trends-2020. Licence: CC BY 4.0.

_____. 2021b. World Electricity Generation Mix by Fuel, 1971-2019. Paris, IEA. www.iea.org/data-and-statistics/charts/world-electricity-generation-mix-by-fuel-1971-2019. Licence: CC BY 4.0.

_____. 2021c. *The Role of Critical Minerals in Clean Energy Transitions*. Paris, IEA. www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions. Licence: CC BY 4.0.

_____. 2022a. People without Access to Electricity Worldwide, 2012-2022. Paris, IEA. www.iea.org/data-and-statistics/charts/people-without-access-to-electricity-worldwide-2012-2022 (Accessed on 17 October 2023).

_____. 2022b. Renewable Power's Growth is being Turbocharged as Countries seek to Strengthen Energy Security. IEA website, 6 December 2022. www.iea.org/news/renewable-power-s-growth-is-being-turbocharged-as-countries-seek-to-strengthen-energy-security.

_____. 2022c. *World Energy Outlook 2022*. Paris, IEA. www.iea.org/reports/world-energy-outlook-2022. Licence: CC BY 4.0 (report); CC BY NC SA 4.0 (Annex A).

_____. 2023. Clean Energy Can Help to Ease the Water Crisis. Paris, IEA. www.iea.org/commentaries/clean-energy-can-help-to-ease-the-water-crisis. Licence: CC BY 4.0.

_____. n.d. Solar PV. IEA website. www.iea.org/energy-system/renewables/solar-pv.

IEA/IRENA/UNSD/World Bank/WHO (International Energy Agency/International Renewable Energy Agency/United Nations Statistics Division/World Bank/World Health Organization). 2023. *Tracking SDG 7: The Energy Progress Report 2023*. Washington, World Bank. mc-cd8320d4-36a1-40ac-83cc-3389-cdn-endpoint.azureedge.net/-/media/Files/IRENA/Agency/Publication/2023/Jun/Tracking_SDG7_energy_progress_2023.pdf?rev=f937758f92a74ab7ac48ff5e8842780a. Licence: CC BY-NC 3.0 IGO.

IHA (International Hydropower Association). 2023. *2023 World Hydropower Outlook: Opportunities to Advance Net Zero.* indd.adobe.com/view/92d02b04-975f-4556-9cfe-ce90cd2cb0dc.

International Battery Metals. 2021. All you need to Know about the Direct Lithium Extraction Process. International Battery Metals website, 24 June 2021. www.ibatterymetals.com/insights/all-you-need-to-know-about-the-direct-lithium-extraction-process.

Jin, Y., Hu, S., Ziegler, A. D., Gibson, L., Campbell, J. E., Xu, R., Chen, D., Zhu, K., Zheng, Y., Ye, B., Ye, F. and Zeng, Z. 2023. Energy production and water savings from floating solar photovoltaics on global reservoirs. *Nature Sustainability*, Vol. 6, pp. 865–874. doi.org/10.1038/s41893-023-01089-6.

Jones, E., Qadir, M., Van Vliet, M. T. H., Smakhtin, V. and Kang, S. 2019. The state of desalination and brine production: A global outlook. *Science of the Total Environment*, Vol. 657, pp. 1343–1356. doi.org/10.1016/j.scitotenv.2018.12.076.

Kagel, A., Bates, D. and Gawell, K. 2007. *A Guide to Geothermal Energy and the Environment*. Washington, Geothermal Energy Association. www.ctc-n.org/sites/default/files/resources/environmental_guide.pdf.

Lorinc, J. and Tuttle, R. 2023. Mining Lithium in Abandoned Oil Fields for Tomorrow's EVs. Bloomberg website, 20 April 2023. www.bloomberg.com/news/articles/2023-04-20/new-lithium-mining-tech-aims-to-disrupt-metal-industry?embedded-checkout=true.

McDonald, B. 2022. *The Future is Now: Solving the Climate Crisis with Today's Technologies*. Toronto, Viking Canada.

NHA (National Hydropower Association). 2021. *2021 Pumped Storage Report*. Washington, NHA. www.hydro.org/wp-content/uploads/2021/09/2021-Pumped-Storage-Report-NHA.pdf.

REN21 (Renewable Energy Policy Network for the 21st Century). 2022. *Renewables 2022 Global Status Report*. Paris, REN21 Secretariat. www.ren21.net/reports/global-status-report/?gclid=EAIaIQobChMIqvag_tbD_QIVJf3jBx3NXAP0EAAYASAAEgKo8vD_BwE.

RFI and Woods, M. 2020. Drought Provokes Shutdown of Nuclear Reactors in Northeast France. RFI website, 25 August 2020. www.rfi.fr/en/france/20200825-drought-provokes-shutdown-nuclear-reactors-northeast-france-belgium-ardennes-chooz-meuse.

Rosa, L., Sánchez, D. L., Realmonte, G., Baldocchi, D. and D'Odorico, P. 2021. The water footprint of carbon capture and storage technologies. *Renewable and Sustainable Energy Reviews*, Vol. 138, Article 110511. doi.org/10.1016/j.rser.2020.110511.

Silva, M. and AFP. 2023. South America's 'Lithium Triangle' Communities are being 'Sacrificed' to save the Planet. Euronews website, last updated 27 February 2023. www.euronews.com/green/2022/10/28/south-americas-lithium-triangle-communities-are-being-sacrificed-to-save-the-planet.

Stolz, P., Frischknecht, R., Heath, G., Komoto, K., Macknick, J., Sinha, P. and Wade, A. 2017. *Water Footprint of European Rooftop Photovoltaic Electricity based on Regionalised Life Cycle Inventories*. IEA PVPS Task 12, International Energy Agency Photovoltaic Power Systems Programme, Report (IEA-PVPS). https://iea-pvps.org/wp-content/uploads/2020/01/Water_Footprint_of_European_Rooftop_Photovoltaic_Electricity_based_in_Re-giornalised_Life_Cycle_Inventories_by_Task_12.pdf.

UNEP/IRP (United Nations Environment Programme/International Resource Panel). 2009. *Towards Sustainable Production and Use of Resources: Assessing Biofuels*. Summary. wedocs.unep.org/handle/20.500.11822/8680.

UNESCO/UN-Water (United Nations Educational, Scientific and Cultural Organization/UN-Water). 2020. *The United Nations World Water Development Report 2020: Water and Climate Change*. Paris, UNESCO. unesdoc.unesco.org/ark:/48223/pf0000372985?posInSet=3&queryId=c45da2c4-7fc7-4be2-be33-5f5a86ee6fca.

United Nations. 2023. *The Sustainable Development Goals Report: Special Edition – Towards a Rescue Plan for People and Planet*. unstats.un.org/sdgs/report/2023/The-Sustainable-Development-Goals-Report-2023.pdf.

WEC (World Energy Council). 2022. *2022 World Energy Issues Monitor. Energy in Uproar: Achieving Commitments through Community Action*. WEC. www.worldenergy.org/assets/downloads/World_Energy_Issues_Monitor_2022_-_Global_Report.pdf?v=1674573393.

Wiatros-Motyka, M. 2023. Global Electricity Review 2023. Ember website, 12 April 2023. ember-climate.org/insights/research/global-electricity-review-2023/.

World Bank. n.d. Annual Freshwater Withdrawals, Total (billion cubic meters). World Bank website. https://data.worldbank.org/indicator/ER.H2O.FWTL.K3. (Accessed October 2023).

WWAP (World Water Assessment Programme). 2003. *Water for People, Water for Life: The United Nations World Water Development Report*. Paris/New York, United Nations Educational, Scientific and Cultural Organization (UNESCO)/Berghahn Books. unesdoc.unesco.org/ark:/48223/pf0000129726.

_____. 2014. *The United Nations World Water Development Report 2014: Water and Energy*. Paris, United Nations Educational, Scientific and Cultural Organization (UNESCO). www.unwater.org/publications/un-world-water-development-report-2014.

_____. 2017. *The United Nations World Water Development Report 2017. Wastewater: The Untapped Resource*. Paris, United Nations Educational, Scientific and Cultural Organization (UNESCO). unesdoc.unesco.org/ark:/48223/pf0000247153.

Chapter 6

Environment

WWAP

David Coates and Richard Connor

IUCN

Maria Carreño Lindelien, James Dalton, Diego Jara and Isabel Wallnoefer

With contribution from: Lilian Daphine Lunyolo (UNFCCC)

"Making peace with nature is the defining task of the 21st century. It must be the top, top priority for everyone, everywhere."

António Guterres, Secretary-General of the United Nations, 2020

6.1 Ecosystem services: trends and lost opportunities

Ecosystems regulate the amount of water available across space and time, as well as its quality. The economic use value of water from freshwater ecosystems in 2021 was estimated at approximately US$58 trillion, equivalent to 60% of global gross domestic product (GDP) (WWF, 2023). This includes a total quantifiable direct use value of a minimum of US$7.5 trillion and an additional US$50 trillion annually, 7 times more, from the indirect benefits that are currently chronically undervalued in policies.

Environmental degradation can be a significant driver of losses in prosperity and amplify socio-political tensions. Losses in ecosystem services reduce benefits, especially to the poorest and most vulnerable groups, and hence increase poverty.

Over-exploitation of provisioning ecosystem services (food, water, fibre and other raw materials) has impaired the capacity of ecosystems to regulate climate and water, among other benefits. Consequences are potentially disastrous and include disputes over environmental resources and the undermining of sustainable prosperity (Dasgupta, 2021).

Water-related ecosystems are by far the most heavily impacted by poor land management, over-use of water and land conversion (IPBES, 2019). The extent and overall condition of wetlands continues to deteriorate globally (Convention on Wetlands, 2021), although estimates vary widely. While Darrah et al. (2019) reported a 35% decline in the natural inland wetland area since 1970, and an 87% total loss since 1700, a more recent estimate suggests a net loss of 21% since 1700 (Fluet-Chouinard et al., 2023). Both studies agree that most of this decline occurred in Europe, China, India and the United States of America (USA).

Water-related ecosystems are by far the most heavily impacted by poor land management, over-use of water and land conversion

Many European countries have drained most of their peatland wetlands, including Germany (98%), the Kingdom of the Netherlands (95%), Denmark (93%) and Ireland (82%) (Joosten et al., 2017). This decline leads to subsidence (sinking), land loss, vulnerability to toxic haze-producing fires and, in coastal peatlands, salinization (FAO, 2020). According to one estimate, restoring peatlands could avoid greenhouse gas (GHG) emissions equivalent to 12–41% of the reductions required to keep global warming below 2°C (Leifeld et al., 2019). In the tropics, drainage is mainly associated with commodity plantations, such as oil palm (IPBES, 2019) and acacia cultivation (Evans et al., 2019).

Forests play a major role in the water cycle, through their influence on evaporation/precipitation regimes, regulation of streamflow, and groundwater recharge. About 75% of the world's accessible freshwater comes from forested watersheds (Springgay, 2019). The rate of deforestation has slowed in recent years, but still, the world lost around 100,000 km^2 of forests per year between 2015 and 2020 (FAO/UNEP, 2020). For instance, Nigerian land contributes 43% of the water evaporation that drives precipitation (rainfall) in neighbouring countries such as Cameroon, Ghana and Guinea. Therefore, besides unsustainable use of surface and groundwater resources, deforestation is another factor that puts water supply in these countries at risk (Rockström et al., 2023). However, the role of forests as 'atmospheric watersheds' – and the need to manage them as such – is increasingly recognized.

Drought is one of the major drivers of global food and water insecurity. In extreme cases, it can force people to abandon their land (IPBES, 2019). There are strong links between land use, land use change, drought and resilience (UNCCD, 2019). Degradation and fragmentation of ecosystems increase the likelihood of conflicts between humans and wildlife (Gibb et al., 2020). They have been linked to outbreaks of diseases, including COVID-19 (UNEP/ILRI, 2020), Ebola (Olivero et al., 2017), and malaria (Morand and Lajaunie, 2021).

Half of the world's GDP is dependent on nature (WEF, 2020). The enormous scale of benefits and opportunities on offer from ecosystem restoration are captured in the declaration of the United Nations Decade on Ecosystem Restoration 2021–2030.[30] The Montreal-Kunming Global Biodiversity Framework has adopted the target of ensuring that by 2030 at least 30% of degraded ecosystem area is under restoration (CBD, 2022). Achieving these ambitions will require transformational change in policies and behaviour.

6.2 Nature, conflict and peacebuilding

Nature can be a casualty of conflict, a cause of conflict or a harbinger of peace. Strengthening gender equality and women's empowerment related to natural resource management can contribute to building effective and lasting peace (IUCN, 2021).

Nature and ecosystem conservation or restoration offer some of the best prospects of achieving a harmonious and prosperous world through the achievement of Sustainable Development Goal 6 (SDG 6): sustainable water and sanitation for all.

Ecosystem degradation can be central to climate change-induced conflict (Box 6.1). In the Sahel region, wetland degradation, often due to ill-advised water development projects, has exacerbated local disputes over access to water and productive land, causing social breakdown and armed conflict, with significant numbers of wetland inhabitants migrating to Europe (Wetlands International, 2017).

Opportunities exist to facilitate peace by harnessing the positive role environmental scientists and educators from both sides can play in dispute resolution

Wildlife–human conflicts can be exacerbated by water resources availability (Box 6.2). Sometimes, wildlife–human conflicts can simultaneously jeopardize conservation and sustainable water resources management objectives. For example, in Pakistan's Ayubia National Park, human–leopard conflicts were on the increase, partly due to water cycle changes driving this critically endangered species closer to local communities. An integrated human–wildlife conflict management plan gained the trust of local communities and paved the way for strong community engagement in various conservation initiatives, where leopards are now seen in a more positive light. Retaliatory killings of leopards have dropped by 50%, and human fatalities have dropped to zero (Gross et al., 2021). Communities are now able to more actively engage in watershed management and protection, which deliver improved water security, while at the same time diversifying their livelihoods through wildlife-based ecotourism.

Opportunities exist to facilitate peace by harnessing the positive role environmental scientists and educators from both sides can play in dispute resolution. A Park for Peace is a special designation that may be applied to any of the three types of transboundary conservation areas, and is dedicated to the promotion, celebration and/or commemoration of peace and cooperation (Vasiljević et al., 2015) (Box 6.3).

[30] Resolution 73/284 adopted by the General Assembly of the United Nations on 1 March 2019.

Box 6.1 Desertification and drought linked to the first recorded climate change conflict

Although multiple factors are in play, Darfur has been labelled the "*first climate change conflict*". In the decades leading up to the 2003 outbreak of war, the Sahel region of northern Sudan had witnessed the Sahara Desert advance southward by over a kilometre each year and a decrease in annual median rainfall of 15–30%. This had significant consequences for Sudan's two predominant and sometimes competing agricultural systems: smallholder farmers relying on rainfed production on the one, and nomadic pastoralists on the other hand, each with differing predominant ethnicities. Accelerating desertification and drought, exacerbated by unsustainable land management, have slowly eroded the availability of the natural resources that support livelihoods and the peaceful coexistence of these two groups in the region. Longstanding pasture and grazing corridors in Sudan shrank to a point where traditional communal land tenure systems could not arbitrate. These factors led to then Secretary-General of the United Nations Ban Ki-moon to comment in 2007, *"Almost invariably, we discuss Darfur in a convenient military and political shorthand, an ethnic conflict pitting Arab militias against black rebels and farmers. Look to its roots, though, and you discover a more complex dynamic. Amid the diverse social and political causes, the Darfur conflict began as an ecological crisis, arising at least in part from climate change."*

Source: Adapted from Sova (2020).

6.3 Valuing nature

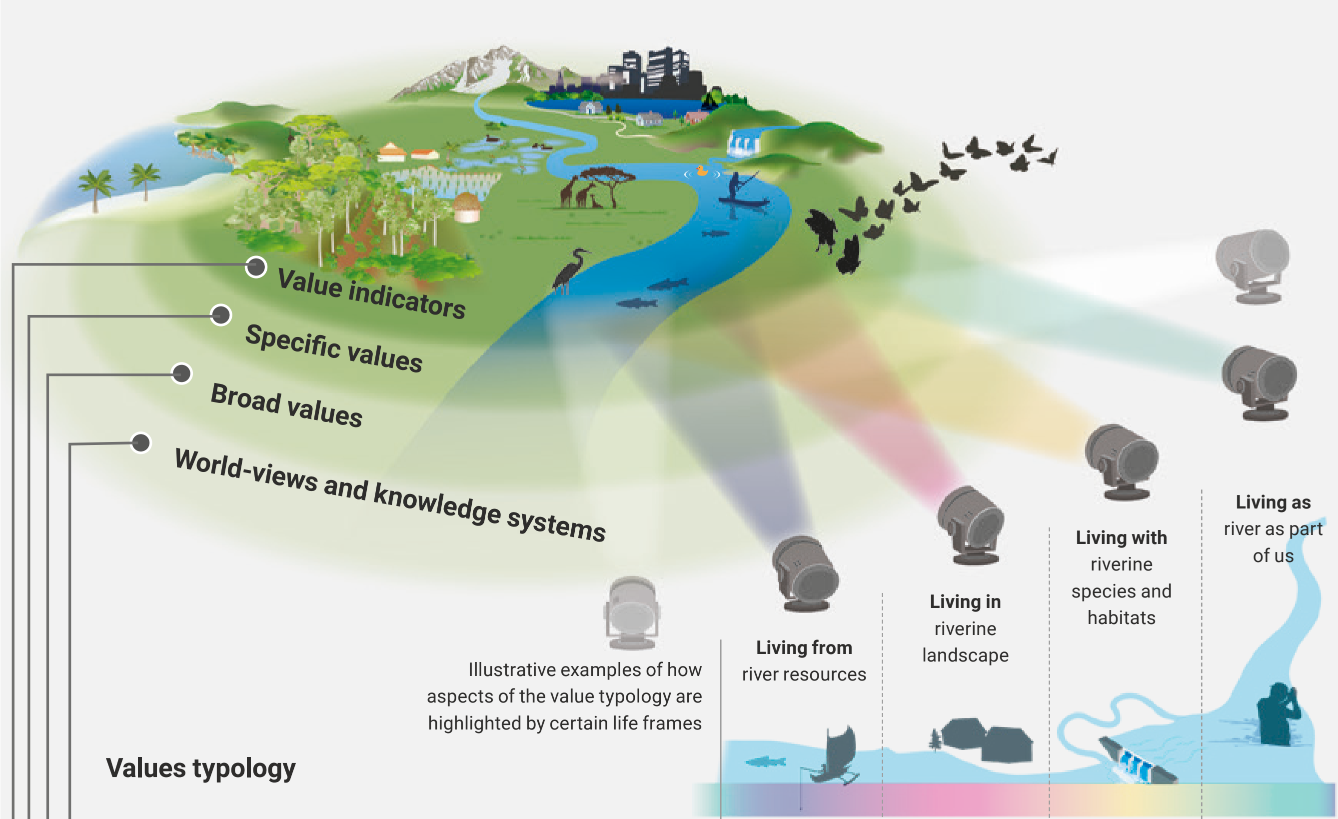
The valuation of ecosystem benefits plays a critical role in leveraging prosperity and peace through water. Policy-making has historically been based on trade-offs among a narrow set of values, prioritizing provisioning ecosystem services (material benefits) over other services (e.g. regulating water or climate and cultural services). "*Ignoring, excluding or marginalizing local values often leads to socio-environmental conflicts linked to value clashes, especially in the context of power asymmetries, which undermine the effectiveness of environmental policies*" (IPBES, 2022, p. 38; Box 6.3). Different value typologies, world views and knowledge systems identify four broad values-based categories of stakeholders – varying from those living ***from*** river resources (largely based on material values), to those living ***in*** riverine landscapes, those living ***with*** riverine species and habitats, and those living with the river ***as part of us*** (Figure 6.1). There is a progressive shift of emphasis from material to non-material values across these perspectives. Although emphasis on the non-material value systems tends to be associated in the literature with traditional and local peoples, they are by no means limited to such groups and can be very evident in other cultures or socio-economic classes.

High values can be attributed to waterscapes (water bodies and their riparian green spaces) through their therapeutic role in physical, mental and social health. For example, a neighbourhood waterscape is more beneficial for psychological and mental health than a neighbourhood green space (Zhang et al., 2021). Yet these important values remain underrepresented in policy and planning.

6.4 Nature-based solutions

The extent of ecosystem degradation and its role in conflict and losses of prosperity highlights the scope for ecosystem restoration to become a dominant response to many water-related challenges, particularly regarding water quality and availability, resilience and responding to climate change. The proactive use of ecosystems is the mantra of nature-based solutions (NbS), the subject of the 2018 edition of the *United Nations World Water Development Report* (WWAP/UN-Water, 2018). Sustainable land management, ecosystem-based adaptation, and ecosystem-based disaster risk reduction are similar proactive effective approaches for improving long-term resilience and human well-being.

Figure 6.1 Values assessment typology: Understanding the diverse values of nature



Values typology

		Living from river resources	**Living in** riverine landscape	**Living with** riverine species and habitats	**Living as** river as part of us
World-views	**Ways through which people conceive and interact with the world**	Anthropocentric	Anthropocentric	Bio/ecocentric	Pluricentric
Knowledge systems	**Bodies of knowledge, practices and beliefs** Academic, indigenous, local			Cosmocentric	
Broad values	**Guiding principles and life goals**	Prosperity, livelihood	Belonging, health	Stewardship, responsibility	Oneness, harmony with nature
Specific values	**Judgements regarding the importance of nature in particular situations**				
	Instrumental: means to an end, nature as a resource and asset, satisfaction of needs and preferences, usefulness for people	Commercial fishery stock	Health benefits of recreation on the river	River as fish habitat	
	Intrinsic: agency of the other-than-humans, inherent worth of biodiversity as ends in and of themselves		Intrinsic value of heritage fish	The right of fish to exist	Fish as co-inhabitants
	Relational: importance of desirable, meaningful, and often reciprocal human relationships	Cultural meanings of fishing	Sense of place of a fishing community	Respect for fish life cycles	Fish as part of kinship or clan relationships
Value indicators	**Quantitative measures and qualitative descriptors**				
	Biophysical	Tonnes of fish	Physiological effects of being in nature	Number of fish species	Nutrition of fish
	Monetary	Market price of fish harvest	Willingness to pay for recreation	Existence value	
	Sociocultural	Gender-specific participation in fishing	Ratings of special places	Legal standing of biodiversity	References to personhood of fish

Note: The figure centres on potential foci of value (e.g. agroecosystems, biodiversity, cities, rivers) and concentric circles illustrate different value types and dimensions (world-views, broad and specific values, nature's contributions to people and value indicators). Life frames are not mutually exclusive; individuals or groups can hold multiple frames.

Source: IPBES (2022, fig. SPM 2, p. 19).

Box 6.2 The case of human–elephant conflict – Ecosystem degradation, water insecurity and the role of landscape restoration

Human–elephant conflict results from increased space and resource competition as human settlements and agriculture expand. Water security, for both people and elephants, is one root cause of conflicts. Poor land management, particularly vegetation removal, and over-extraction of water lead to dwindling, and increasing variability of, water resources – a situation further exacerbated by climate change. These human-induced changes not only cause reduced agricultural productivity, but also reduce the forage availability for elephants, and the surface water availability for all. Hence competition increases. India alone reports annual deaths of 400 people and 100 elephants during such incidents, with additional direct effects to 500,000 families through crop raiding. Sri Lanka annually documents over 70 human and 200 elephant mortalities from conflict, whilst Kenya reports that 50–120 problematic elephants are shot by wildlife authorities each year and about 200 people died in human–elephant conflict between 2010 and 2017. Other Asian and African range countries document similar or worse consequences. Current conflict management approaches focus on prevention through exclusion and on-site deterrents, many of which are nature-based. Examples include the use of spices or bees as deterrents, mitigation via elephant translocation or selective culling and monetary compensation for losses. However, these merely address the symptoms of the problem. Sustainable solutions require site-specific measures to be framed within landscape level restoration planning that addresses patterns of water and vegetation quality and quantity across space and time. Improving landscape productivity and water security underpins long-term promotion of peaceful coexistence between people and nature.

Source: Shaffer et al. (2019).

Box 6.3 The Salween Peace Park – An indigenous people-led initiative to promote peace and protect the Salween River basin

The Salween River, crossing China, Myanmar and Thailand, is the longest remaining free-flowing river in Asia. In the Karen state of Myanmar, the rivers of the basin provide valuable services. They also have spiritual value and are sacred to the local indigenous people. The area has suffered over 70 years of conflict, including armed episodes.

Created in 2018 to promote sustainable peace, the Salween Peace Park (SPP) spans over 6,000 km^2 of a highly biodiverse landscape. The SPP is a community-led initiative that empowers local indigenous communities to revitalize their traditional practices, ensure the basin's conservation, and support water management by conserving critical ecosystems. The SPP is managed sustainably by indigenous Karen communities through an inclusive democratic governance structure that provides spaces for local people to converse on equal footing. The SPP was one of the winners of the 2020 Equator Prize.[a]

This initiative is facing multiple pressures from resource extraction, hydropower development proposals and territorial contentions. Since military action in 2021, displacement and livelihood disruption have stalled community-led management and monitoring activity.

Source: Equator Initiative (2021); Kantar (2019); with inputs from Paul Sein Twa (Salween Peace Park General Assembly/Karen Environmental and Social Action Network (KESAN)).

[a] For more information, please see www.undp.org/press-releases/2020-equator-prize-winners-show-nature-based-solutions-ahead-un-biodiversity-summit.

Nature-based solutions usually provide multiple benefits, including several related to local prosperity, and are increasingly proving to be cost-effective

By 2030, 150 million people a year could need humanitarian assistance due to floods, droughts, and storms and by 2050, this is expected to have risen to 200 million people annually (IFRC, 2019). Implementing NbS could reduce the number of people in need of international humanitarian assistance due to climate change and weather-related disasters. However, some significant challenges remain for NbS to reach their potential, including the need to better understand their limits, issues of participation and equity, lack of methods for economic valuation, scalar mismatches, difficulties with integrating natural and built infrastructure, inadequate governance, and the need to fundamentally rethink society's relationship with nature (Nelson et al., 2020).

NbS usually provide multiple benefits, including several related to local prosperity, and are increasingly proving to be cost-effective. For example, soils represent around 25% of the NbS required for climate change mitigation to achieve the Paris Agreement, whilst simultaneously delivering improved crop water availability and groundwater recharge. Half of this is considered low-cost, requiring an investment of US$10 per tonne of CO_2 avoided (Bossio et al., 2020). Restoration of mangroves could protect more than 267,000 people in the Philippines from flooding, saving US$450 million per year in damage (Losada et al., 2018). Agroforestry alone has the potential to increase food security for 1.3 billion people (Smith et al., 2019). It can also reduce soil erosion by 50% and increase soil carbon content by 21%, inorganic nitrogen by 46% and phosphorus by 11%, all of which can directly improve livelihoods of local farmers, as well as the water quality in their area (Muchane et al., 2020).

The evidence for the job creation potential of NbS projects is significant and increasing (OECD, 2020). There is a range of practical and implementable NbS that can be deployed to help address the biodiversity and climate crises, while simultaneously creating sustainable jobs and long-term prosperity (Van Zanten et al., 2023). Every dollar invested in ecosystem restoration can create up to US$30 in economic benefits (Ding et al., 2018). Investment in landscape-scale restoration in the USA creates at least twice as many jobs as a similar investment in the oil and gas sector would (Calderón, 2017). New Zealand has dedicated US$700 million in recovery funds towards 11,000 restoration jobs (Government of New Zealand, 2020). By planting 5 billion seedlings, Ethiopia's forest cover is to be doubled by 2030, creating green jobs (Federal Democratic Republic of Ethiopia, 2020). South Africa has invested US$1.15 billion in restoration, including as part of the "Working for Water" initiative that has used job creation since 1995 to clear three million hectares of invasive species that affect water quality through an increased fire risk and subsequent soil erosion (CBD, 2018). In Ecuador, a payment-for-ecosystem-services scheme enabled local indigenous communities to hire forest guards and clear trails for a land demarcation programme, resulting in reduced deforestation rates and fewer invasions into their territories (Perefán and Pabón, 2019).

Ecosystem restoration is now recognized as an urgent and key element for conflict resolution and peacebuilding, as well as a tool to improve access to resources, manage climate-related security risks, reduce recruitment by terrorist groups and alleviate pressure on people to migrate (Barbut and Alexander, 2016; UNEP, 2019; United Nations, 2020). Eighty-one percent of Parties to the United Nations Framework Convention on Climate Change includes ecosystem restoration in their nationally determined contributions (UNFCCC, 2022), although there is limited information on implementation. By reducing resource scarcity, increasing income generation, and aiding mitigation and adaptation to climate change, restoration can address some of the main drivers of environmentally triggered human migration (UNCCD, 2018; IPBES, 2019).

6.5 Response options

Assessments of the state and trajectory of the environment have consistently highlighted the urgent need for transformational change in humankind's relationship with it, noting the disastrous consequences of 'business as usual'.[31] Despite this, now long history of repeatedly identifying the problem and needs, implementation of measures to achieve a sustainable pathway still fall well short of what is required.

The IPBES (2022) noted the need to institutionalize and integrate the diverse values of nature and its contributions to people. A key factor is recognizing how access to nature's contributions is inequitably distributed across individuals, groups, and generations. Lack of information, lack of technical and financial resources, and other capacity gaps hinder the inclusion of diverse values of nature in decision-making, but capacity-building and collaborations among a broad range of societal actors can help bridge these gaps.

Opportunities for accelerating uptake of NbS include leveraging existing financing towards more 'green' investments, expanding innovative financing mechanisms, creating regulatory and legal enabling environments that support rather than constrain NbS investments, enhancing intersectoral collaboration and harmonizing policy domains, and improving the knowledge base, with more rigorous assessments and evaluations (WWAP/UN-Water, 2018). The *IUCN Global Standard for Nature-based Solutions* (IUCN, 2020) has introduced a methodology for standardization across NbS applications that will help promote an improved NbS uptake, using a set of common indicators: societal challenges, design at scale, biodiversity net gain, economic feasibility, inclusive governance, balancing trade-offs, adaptive management, sustainability, and mainstreaming. The World Bank has recently provided practical guidance for integrating grey and green infrastructure (Browder et al., 2019) and for assessing the benefits and costs of NbS for climate resilience (Van Zanten et al., 2023).

Policy responses for conserving nature and building peace include:

i. Improved natural resources governance through inclusive decision-making, the strengthening of land tenure and resource rights, accountability and transparency, upholding of the rights of indigenous peoples, gender equality and women's empowerment, and improved coordination within countries;

ii. Improved natural resources management, including through protected areas, post-conflict rebuilding, sustainable land and water management, applying of standards and safeguards, and greening of military and humanitarian operations;

iii. Nature protection in areas of conflict, including through the application and implementation of international agreements, and the enforcement of obligations from international court rulings; and

iv. Transboundary resources management and agreements, including water diplomacy, and parks for peace (IUCN, 2021).

[31] For example: The Millennium Ecosystem Assessment (2005) and follow up assessment (IPBES, 2019); consistently throughout the five editions of the *Global Biodiversity Outlook* since 1999 to 2021 (CBD, n.d.); throughout the seven editions of the *Global Environment Outlook* from 1995 to 2022 (UNEP, n.d.); the Kunming-Montreal *Global Biodiversity Framework* of 2022 (CBD, 2022), and its precursor the *Strategic Plan for Biodiversity 2011–2020* (CBD, 2010); and, as encapsulated in the 2030 Agenda for Sustainable Development and the Sustainable Development Goals.

References

Barbut, M. and Alexander, S. 2016. Land degradation as a security threat amplifier: The new global frontline. I. Chabay, M. Frick and J. Helgenson, J. (eds.), *Land Restoration*. Academic Press. pp. 3–12. doi.org/10.1016/B978-0-12-801231-4.00001-X.

Bossio, D. A., Cook-Patton, S. C., Ellis, P. W., Fargione, J., Sanderman, J., Smith, P., Wood, S., Zomer, R. J., Von Unger, M., Emmer, I. M. and Griscom, B. W. 2020. The role of soil carbon in natural climate solutions. *Nature Sustainability*, Vol. 3, No. 5, pp. 391–398. doi.org/10.1038/s41893-020-0491-z.

Browder, G., Ozment, S., Rehberger Bescos, I., Gartner, T. and Lange, G.-M., 2019. *Integrating Green and Gray: Creating Next Generation Infrastructure*. Washington, World Bank/World Resources Institute. http://hdl.handle.net/10986/31430. Licence: CC BY 4.0.

Calderón, F. 2017. *The Restoration Revolution*. World Resources Institute (WRI) website. www.wri.org/insights/restoration-revolution.

CBD (Convention on Biological Diversity). 2010. *Decision Adopted by the Conference of the Parties to the Convention on Biological Diversity*. X/2. The Strategic Plan for Biodiversity 2011-2020 and the Aichi Biodiversity Targets. UNEP/CBD/COP/DEC/X/2. www.cbd.int/doc/decisions/cop-10/cop-10-dec-02-en.pdf.

_____. 2018. *South Africa: 6th National Report for the Convention on Biological Diversity*. https://chm.cbd.int/pdf/documents/nationalReport6/241240/2.

_____. 2022. *Decision Adopted by the Conference of the Parties to the Convention on Biological Diversity*. 15/4. Kunming-Montreal Global Biodiversity Framework. CBD/COP/DEC/15/4. www.cbd.int/doc/decisions/cop-15/cop-15-dec-04-en.pdf.

_____. n.d. The Global Biodiversity Outlook 5. CBD website. www.cbd.int/gbo5. (Accessed on 1 May 2023).

Convention on Wetlands. 2021. *Global Wetland Outlook: Special Edition 2021*. Gland, Switzerland, Secretariat of the Convention on Wetlands. www.global-wetland-outlook.ramsar.org/report-1.

Darrah, S. E., Shennan-Farpón, Y., Loh, J., Davidson, N. C., Finlayson, C. M., Gardner, R. C. and Walpole, M. J. 2019. Improvements to the Wetland Extent Trends (WET) index as a tool for monitoring natural and human-made wetlands. *Ecological Indicators*, Vol. 99, pp. 294–298. doi.org/10.1016/j.ecolind.2018.12.032.

Dasgupta, P. 2021. *The Economics of Biodiversity: The Dasgupta Review*. London, HM Treasury. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/962785/The_Economics_of_Biodiversity_The_Dasgupta_Review_Full_Report.pdf.

Ding, H., Faruqi, S., Wu, A., Altamirano, J.-C., Anchondo Ortega, A., Zamora-Cristales, R., Chazdon, R., Vergara, W. and Verdone, M. 2018. *Roots of Prosperity: The Economics and Finance of Restoring Land*. Washington, DC, World Resources Institute (WRI). www.wri.org/research/roots-prosperity-economics-and-finance-restoring-land.

Equator Initiative. 2021. *Hkolo Tamutaku K'Rer (Salween Peace Park)*. Republic of the Union of Myanmar. Equator Initiative Case Studies: Local Sustainable Development Solutions for People, Nature, and Resilient Communities. New York, Equator Initiative, Sustainable Development Cluster, United Nations Development Programme (UNDP). www.equatorinitiative.org/wp-content/uploads/2020/06/Salween-Peace-Park-Case-Study-English-FNL.pdf.

Evans, C. D., Williamson, J. M., Kacaribu, F., Irawan, D., Suardiwerianto, Y., Hidayat, M. F., Laurén, A. and Page, S. E. 2019. Rates and spatial variability of peat subsidence in Acacia plantation and forest landscapes in Sumatra, Indonesia. *Geoderma*, Vol. 338, pp. 410–421. doi.org/10.1016/j.geoderma.2018.12.028.

FAO (Food and Agriculture Organization of the United Nations). 2020. *Peatland Mapping and Monitoring: Recommendations and Technical Overview*. Rome, FAO. doi.org/10.4060/ca8200en.

FAO/UNEP (Food and Agriculture Organization of the United Nations/United Nations Environment Programme). 2020. *The State of the World's Forests. Forests, Biodiversity and People*. Rome, FAO. doi.org/10.4060/ca8642en.

Federal Democratic Republic of Ethiopia. 2020. *Prime Minister Abiy Launches 2020 Green Legacy Tree-Planting programme*, 8 June 2020. Embassy of the Federal Democratic Republic of Ethiopia website. www.ethioembassy.org.uk/prime-minister-abiy-launches-2020-green-legacy-tree-planting-programme/. (Accessed on 26 April 2023).

Fluet-Chouinard, E., Stocker, B. D., Zhang, Z., Malhotra, A., Melton, J. R., Poulter, B., Kaplan, J. O., Klein Goldewijk, K., Siebert, S., Minayeva, T., Hugelius, G., Joosten, H., Barthelmes, A., Prigent, C., Aires, F., Hoyt, A. M., Davidson, N., Finlayson, C. M., Lehner, B., Jackson, R. B. and McIntyre, P. B. 2023. Extensive global wetland loss over the past three centuries. *Nature*, Vol. 614, pp. 281–286. doi.org/10.1038/s41586-022-05572-6.

Gibb, R., Redding, D. W., Chin, K. Q., Donnelly C. A., Blackburn, T. M., Newbold, T. and Jones, K. E. 2020. Zoonotic host diversity increases in human-dominated ecosystems. *Nature*, Vol. 584, pp. 398–402. doi.org/10.1038/s41586-020-2562-8.

Government of New Zealand. 2020. *Summary of Initiatives in the Covid-19 Response and Recovery Fund (CRRF) Foundational Package*. New Zealand Government. treasury.govt.nz/publications/summary-intiatives/summary-initiatives-crrf-budget2020.

Gross, E., Jayasinghe, N., Brooks, A., Polet, G., Wadhwa, R. and Hilderink-Koopmans, F. 2021. *A Future for All: The Need for Human-Wildlife Coexistence*. Gland, Switzerland, World Wide Fund For Nature (WWF). https://updates.panda.org/human-wildlife-conflict-report.

IFRC (International Federation of Red Cross and Red Crescent Societies). 2019. *The Cost of Doing Nothing: The Humanitarian Price of Climate Change and How It Can Be Avoided*. Geneva, IFRC. www.ifrc.org/sites/default/files/2021-07/2019-IFRC-CODN-EN.pdf.

IPBES (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services). 2019. *Summary for Policymakers of the Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. Bonn, Germany, IPBES. doi.org/10.5281/zenodo.3553579.

_____. 2022. *Summary for Policymakers of the Methodological Assessment Report on the Diverse Values and Valuation of Nature of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. Bonn, Germany, IPBES Secretariat. doi.org/10.5281/zenodo.6522392.

IUCN (International Union for Conservation of Nature). 2020. *IUCN Global Standard for Nature-based Solutions: A User-Friendly Framework for the Verification, Design and Scaling Up of NbS*. First edition. Gland, Switzerland, IUCN. doi.org/10.2305/IUCN.CH.2020.08.en.

_____. 2021. *Conflict and Conservation: Nature in a Globalised World*. Report No. 1. Gland, Switzerland, IUCN. doi.org/10.2305/IUCN.CH.2021.NGW.1.en.

Joosten, H., Tanneberger, F. and Moen, A. 2017. *Mires and Peatlands of Europe: Status, Distribution and Conservation*. Stuttgart, Germany, Schweizerbart Science Publishers.

Kantar, S. 2019. Karen minority urges 'respect' in Myanmar peace park initiative. Al Jazeera, 31 January 2019. www.aljazeera.com/news/2019/1/31/karen-minority-urges-respect-in-myanmar-peace-park-initiative.

Leifeld, J., Wüst-Galley, C. and Page, S. 2019. Intact and managed peatland soils as a source and sink of GHGs from 1850 to 2100. *Nature Climate Change*, Vol. 9, No. 12, pp. 945–947. doi.org/10.1038/s41558-019-0615-5.

Losada, I.J., Menéndez, P., Espejo, A., Torres, S., Díaz-Simal, P., Abad, S., Beck, M. W., Narayan, S., Trespalacios, D., Pfliegner, K., Mucke, P. and Kirch, L. 2018. *The Global Value of Mangroves for Risk Reduction.* Technical Report. Berlin, The Nature Conservancy. doi.org/10.7291/V9DV1H2S.

Millennium Ecosystem Assessment. 2005. *Ecosystems and Human Well-Being: Synthesis*. Washington, DC, Island Press. www.millenniumassessment.org/documents/document.356.aspx.pdf.

Morand, S. and Lajaunie, C. 2021. Outbreaks of vector-borne and zoonotic diseases are associated with changes in forest cover and oil palm expansion at global scale. *Frontiers in Veterinary Science*, Vol. 8, Article 661063. doi.org/10.3389/fvets.2021.661063.

Muchane, M. N., Sileshi, G. W., Gripenberg, S., Jonsson, M., Pumariño, L. and Barrios, E. 2020. Agroforestry boosts soil health in the humid and sub-humid tropics: A meta-analysis. *Agriculture, Ecosystems and Environment*, Vol. 295, Article 106899. doi.org/10.1016/j.agee.2020.106899.

Nelson, D. R., Bledsoe, B. P., Ferreira, S. and Nibbelink, N. P. 2020. Challenges to realizing the potential of nature-based solutions. *Current Opinion in Environmental Sustainability*, Vol. 45, pp. 49–55. doi.org/10.1016/j.cosust.2020.09.001.

OECD (Organisation for the Economic Co-operation and Development). 2020. *Biodiversity and the Economic Response to COVID-19: Ensuring a Green and Resilient Recovery.* OECD Policy Responses to Coronavirus (COVID-19). Paris, OECD. www.oecd.org/coronavirus/policy-responses/biodiversity-and-the-economic-response-to-covid-19-ensuring-a-green-and-resilient-recovery-d98b5a09/.

Olivero, J., Fa, J. E., Real, R., Farfán, M. Á., Márquez, A. L., Vargas, J. M., González, J. P., Cunningham, A. A. and Nasi, R. 2017. Mammalian biogeography and the Ebola virus in Africa. *Mammal Review*, Vol. 47, No. 1, pp. 24–37. doi.org/10.1111/mam.12074.

Perefán, C. and Pabón, M. 2019. *Comunidades Sostenibles: Evaluación Socio Cultural del Programa Socio Bosque* [Sustainable Communities: Socio-Cultural Evaluation of the Programme Socio Bosque]. Inter-American Development Bank (IDB). doi.org/10.18235/0001643. (In Spanish.)

Rockström, J., Mazzucato, M., Andersen, L., Fahrländer, S. and Dieter, G. 2023. Why we need a new economics of water as a common good. *Nature*, Vol. 615, No. 7954, pp. 794–797. doi.org/10.1038/d41586-023-00800-z.

Shaffer, L. J., Khadka, K. K., Van den Hoek, J. and Naithani, K. J. 2019. Human-elephant conflict: A review of current management strategies and future directions. *Frontiers in Ecology and Evolution*, Vol. 6, doi.org/10.3389/fevo.2018.00235.

Smith, P., Nkem, J., Calvin, K., Campbell, D., Cherubini, F., Grassi, G., Korotkov, V., Hoang, A. L., Lwasa, S., McElwee, P., Nkonya, E., Saigusa, N., Soussana, J. -F. and Taboad, M. A. 2019. Interlinkages between desertification, land degradation, food security and greenhouse gas fluxes: Synergies, trade-offs and integrated response options. P. R. Shukla, J. Skea, E. Calvo Buendía, V. Masson-Delmotte, H.-O. Pörtner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi and J. Malley (eds.), *Climate Change and Land: An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems*. Intergovernmental Panel on Climate Change (IPCC). www.ipcc.ch/srccl/.

Sova, C. 2020. The first climate change conflict. WFP USA website. www.wfpusa.org/articles/the-first-climate-change-conflict/. (Accessed on 12 May 2023).

Springgay, E. 2019. Forests as nature-based solutions for water. *Unasylva: An International Journal of Forestry and Forest Industries*, Vol. 90, No. 2019/1, pp. 3–13. www.fao.org/3/ca6842en/CA6842EN.pdf.

UNCCD (United Nations Convention to Combat Desertification). 2018. Caux Dialogue on Land and Security: Creating Landscapes of Peace. 27 July 2018. UNCCD website. www.unccd.int/news-events/caux-dialogue-land-and-security-creating-landscapes-peace. (Accessed on 26 April 2021).

_____. 2019. *Land Management and Drought Mitigation.* Science-Policy Brief No. 6. September 2019. Bonn, Germany, UNCCD. www.unccd.int/resources/brief/land-management-and-drought-mitigation-science-policy-brief.

UNEP (United Nations Environment Programme). 2019. *Restore Landscapes to Push Ahead on Sustainable Development, says International Resource Panel*. Press Release, Nairobi, 5 September 2019. www.unep.org/news-and-stories/press-release/restore-landscapes-push-ahead-sustainable-development-says.

_____. n.d. *The Global Environment Outlook*. UNEP website. www.unep.org/geo/. (Accessed on 1 May 2023).

UNEP/ILRI (United Nations Environment Programme/International Livestock Research Institute). 2020. *Preventing the Next Pandemic: Zoonotic Diseases and How to Break the Chain of Transmission*. Nairobi, UNEP/ILRI. www.unep.org/resources/report/preventing-future-zoonotic-disease-outbreaks-protecting-environment-animals-and.

UNFCCC (United Nations Framework Convention on Climate Change). 2022. *Nationally Determined Contributions under the Paris Agreement. Synthesis Report by the Secretariat*. Fourth session of the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement. FCCC/PA/CMA/2022/4. https://unfccc.int/documents/619180.

United Nations. 2020. Climate Emergency 'a Danger to Peace', UN Security Council Hears. UN News, 24 July 2020. https://news.un.org/en/story/2020/07/1068991.

Van Zanten, B. T., Gutiérrez Goizueta, G., Brander, L. M., González Reguero, B., Griffin, R., Macleod, K. K., Alves Beloqui, A. I., Midgley, A., Herrera García, L. D. and Jongman, B. 2023. *Assessing the Benefits and Costs of Nature-Based Solutions for Climate Resilience: A Guideline for Project Developers*. Washington, World Bank. http://hdl.handle.net/10986/39811.

Vasilijević, M., Zunckel, K., McKinney, M., Erg, B., Schoon, M. L. and Rosen Michel, T. 2015. *Transboundary Conservation: A Systematic and Integrated Approach*. Best Practice Protected Area Guidelines Series No. 23. Gland, Switzerland, International Union for Conservation of Nature (IUCN). https://portals.iucn.org/library/node/45173.

WEF (World Economic Forum). 2020. *The Global Risks Report 2020*. Geneva, WEF. www.weforum.org/reports/the-global-risks-report-2020/.

Wetlands International. 2017. *Water Shocks: Wetlands and Human Migration in the Sahel.* Wageningen, The Netherlands, Wetlands International. www.wetlands.org/publications/water-shocks-wetlands-human-migration-sahel/.

WWAP/UN-Water (UNESCO World Water Assessment Programme/UN-Water). 2018. *The United Nations World Water Development Report 2018: Nature-Based Solutions for Water*. Paris, United Nations Educational, Scientific and Cultural Organization (UNESCO). https://unesdoc.unesco.org/ark:/48223/pf0000261424.

WWF (World Wide Fund For Nature). 2023. *The High Cost of Cheap Water: The True Value of Water and Freshwater Ecosystems to People and Planet*. Gland, Switzerland, WWF. www.worldwildlife.org/publications/high-cost-of-cheap-water-the-true-value-of-water-and-freshwater-ecosystems-to-people-and-planet.

Zhang, X., Zhang, Y., Zhai, J., Wu, Y. and Mao, A. 2021. Waterscapes for promoting mental health in the general population. *International Journal of Environmental Research and Public Health*. Vol. 18, No. 22, Article 11792. doi.org/10.3390/ijerph182211792.

Chapter 7

Transboundary cooperation

UNESCO IHP

Raya Marina Stephan and Aurélien Dumont

UNECE

Remy Kinna and Sonja Koeppel

With contributions from: Katie Goldie-Ryder, Julieen Ngo Yebga and Kerry Schneider (SIWI), Martina Klimes (on behalf of the ICWC hosted by SIWI), Susanne Schmeier (IHE Delft), Arnaud Sterckx (IGRAC), Vishwaranjan Sinha (IUCN), Jonathan Lautze and Girma Ebrahim (IWMI), Zione Uka (Department of Water Resources, Malawi), Francisco Macarringue (ARA-Centro, Mozambique), Fabiola Tábora (GWP Central America), Yumiko Yasuda (GWP), and José Vieira, Ignacio González-Castelao and Tomás Sancho (WFEO)

Transboundary rivers, lakes and aquifers account for 60% of the world's freshwater flows (UNECE/UNESCO, 2021). Over 310 river basins and an estimated 468 aquifers are shared between two or more countries (McCracken and Wolf, 2019; IGRAC, 2021). A total of 153 countries share rivers, lakes and aquifers.

Transboundary waters globally face significant and increasing pressures due to population increase, growing water demands, ecosystem degradation and climate change. Cooperation over transboundary rivers, lakes and aquifers can generate multiple economic, social, environmental and political benefits that in turn deliver prosperity and peace at local, national, regional and global levels. The topic has drawn attention at high levels at the United Nations (UN), including through the Global High-Level Panel on Water and Peace established in 2017. The UN Security Council[32] has also recognized that joint water management can foster trust, stability and peace.

Throughout history, countries have developed context-specific governance arrangements that foster peace and prosperity over transboundary waters

It is imperative for states to cooperate over their transboundary waters, as reflected in the Sustainable Development Goal (SDG) Target 6.5 *"by 2023, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate."* The UN 2023 Water Conference called for the strengthening of transboundary water cooperation as a means by which to accelerate progress on sustainable development and regional integration, and to build sustainable peace (United Nations, 2023).

Water can bring countries together and promote prosperity by providing common livelihood, development and cost-sharing opportunities that may exceed those generated by unilateral action. International water law has developed principles and norms that provide the basis for transboundary water cooperation, which can help solve disputes and contribute to stability and peace. *The Convention on the Law of Non-Navigational Uses of International Watercourses* (Watercourses Convention; United Nations, 1997) and *the Convention on the Protection and Use of Transboundary Watercourses and International Lakes* (Water Convention; UNECE, 2013), as well as the *Draft Articles on the Law of Transboundary Aquifers (*ILC, 2008), provide riparian states with basic norms for: equitable and reasonable utilization of the joint water body; the duty to do no significant harm; and the duty to cooperate. The two UN water conventions include provisions for the peaceful settlement of disputes. The Water Convention also has an implementation committee specifically aimed at preventing and resolving disputes.

In addition, regional integration bodies, such as the European Union and several regional economic communities across Africa,[33] promote cooperation and peace through their coordination actions across sectors and river, lake and aquifer systems.

Throughout history, countries have developed context-specific governance arrangements that foster peace and prosperity over transboundary waters. Research suggests that "*coordination between stakeholders, through the establishment of institutional capacity in the form of agreements, treaties or informal working relationships, can help reduce the likelihood of conflict. Once institutional capacity is established between parties it has been proven to be resilient over time, even as conflict was being waged over other issues"* (Petersen-Perlman et al., 2017, p. 2).

'Water diplomacy' seeks to facilitate the political processes and practices aimed at preventing, mitigating and resolving disputes over transboundary water resources, and the development of joint water governance arrangements by applying foreign policy means at different tracks and levels (Sehring et al., 2022). It can ease tensions between states while

---

[32] On 22 November 2016 under the Presidency of Senegal; on 6 June 2017 under the Presidency of Belgium and Bolivia; and on 26 October 2018 co-hosted by Côte d'Ivoire, the Dominican Republic, Germany, Indonesia, Italy and the Kingdom of the Netherlands.

[33] Examples include the Southern African Development Community, the Economic Community of West African States and the Economic Community of Central African States.

improving governance over their shared waters and maintaining or strengthening regional relations. Water diplomacy can involve actors other than traditional state actors, including civil society organizations or academic networks (Mirumachi, 2020; Denoon et al., 2020).

While over 3,600 international water treaties have been developed since CE 805 (UNEP/OSU/FAO, 2002) and approximately 120 international basin organizations exist to jointly manage shared basins worldwide (OSU, n.d.), many transboundary water bodies still lack such arrangements. Only 32 out of the 153 countries sharing transboundary waters have at least 90% of their transboundary basin area covered by an operational arrangement for water cooperation (UNECE/UNESCO, 2021), and there are very few aquifer-specific agreements (Burchi, 2018).

7.1 Transboundary water agreements and institutions

Agreements coupled with operational joint bodies and international and multi-lateral operational arrangements for transboundary waters can be important assets of preventive diplomacy. As such, they are unique features of international cooperation in the pursuit of shared water management and solutions to the related challenges (Global High-Level Panel on Water and Peace, 2017). Transboundary water management is a long-term and often challenging process. Agreements and institutions can provide additional guidance and clarity for the parties in negotiation, coordinated planning and implementation, and dispute resolution.

The Senegal River Basin Development Organization (OMVS) is a comprehensive, institutionally developed management system that has served as an instrument of cooperation among riparian states (UNDP/GEF, 2011). The OMVS was created in the early 1970s by the heads of state of Mali, Mauritania and Senegal, with the purpose to promote joint management of the shared water resources in the face of drought. The organization enabled communication between Mauritania and Senegal during a period of conflict (Auclair and Lasserre, 2013).

7.2 Role of transboundary water cooperation in conflict and post-conflict settings

Many transboundary basins are in areas marked by current or past interstate tensions and, in certain contexts, armed conflicts, both among and within states (Global High-Level Panel on Water and Peace, 2017). Cooperation on transboundary water management can serve as an entry point for promoting peace in conflict and post-conflict situations (Box 7.1). For example, "*water cooperation has been a part of numerous peace treaties in Europe: the Rhine and the Danube water cooperation systems that exist today are the results of peace agreements in Vienna (1815) and in Paris (1856), respectively*" (Global High-Level Panel on Water and Peace, 2017, p. 14).

In a post-conflict setting, the *Framework Agreement on the Sava River Basin* (FASRB) (Bosnia and Herzegovina/Republic of Croatia/Republic of Slovenia/Federal Republic of Yugoslavia, 2002) represents the first multilateral, development-oriented agreement in South-East Europe concluded after the *General Framework Agreement for Peace in Bosnia and Herzegovina* (General Assembly of the United Nations/Security Council, 1995) and the *Agreement on Succession Issues* (United Nations, 2001). The FASRB provides the framework for cooperation on water resources and navigation in the context of promoting conditions for sustainable development across the Sava River basin countries (see Box 8.2). The agreement established a Commission as the decision-making body. It meets regularly and has elaborated various plans in conformity with the agreement.

Representing the largest inland drainage area in Africa, the Lake Chad basin has grappled with various forms of conflict and insecurity for decades (UNDP, 2022). Its drainage basin (984,455 km^2) is shared by the Lake Chad Basin Commission (LCBC) member states: Cameroon, Chad, the Central African Republic, Libya, Niger and Nigeria. Damming, overextraction, climate change and drought are all leading to the rapid depletion of the lake. Measurements taken during the last decade reveal that the lake had decreased in size by 90% over the previous 60 years. This has contributed to significant unemployment and a broad range of security challenges in the region (Supreme State Audit Office of Cameroon/Court of Accounts Chad/Court of Accounts Niger/Office of the Auditor-General for the Federation of Niger, 2015).

In a context of growing water scarcity, the LCBC has been entrusted by its member states with ensuring the most efficient use of the basin's waters, coordinating development and assisting in the settlement of any dispute that might arise between the riparian countries (Cameroon/Chad/Niger/Nigeria, 1964). The *Water Charter for the Lake Chad Basin* was updated in 2011, thereby requiring *"State Parties [...] to cooperate to achieve the sustainable management and development of Lake Chad in compliance with the rules and principles governing international lakes and watercourses"* (LCBC, 2011, Article 1). LCBC's mandate expanded over time, making it an appropriate institution for addressing the specific needs of the basin, including socio-economic development and security issues. Moreover, in a region facing insecurity and attacks from armed groups, the LCBC has reactivated and hosts the Multi-national Joint Task Force as a regional security arrangement. While river basin organizations are generally mandated to focus on transboundary water management, the case of LCBC illustrates how they can promote regional peace and security more broadly.

7.3 Inclusive, participatory transboundary processes

Inclusive and participatory transboundary water cooperation platforms and processes lead to a common understanding of their objectives and benefits. The inclusion of minority and often-marginalized groups was a common theme at the UN 2023 Water Conference, which highlighted the benefits of active participation by women and indigenous peoples (United Nations, 2023). Indigenous and traditional communities may have long-standing networks across borders. Situating them in the centre of dialogues represents an opportunity for enhancing transboundary cooperation.

The Meghna River is one of the last free-flowing rivers in South Asia. Its basin is shared by Bangladesh and India and home to several indigenous forest-dependent and rural communities (the Chakpa, Garo, Jaintia and Khasi). Based on the understanding that these transboundary riparian communities have cooperated in various ways over generations, joint research initiatives and multi-stakeholder benefit-sharing dialogues are being piloted here, including the first-ever Meghna knowledge-sharing forum, to learn from riparian communities' traditional knowledge and methods in supporting bottom-up approaches to cooperation (IUCN, n.d.).

Across the world, women remain generally underrepresented in the water sector, and in the transboundary water sector specifically (Fauconnier et al., 2018). All scales of water cooperation require the meaningful participation of women, including development and peacebuilding processes, conflict prevention and resolution, and post-conflict reconstruction and recovery.

The Women in Water Diplomacy Network[34] seeks to connect and engage women in decision and policy-making and as water experts by developing their capacities in water diplomacy, negotiation, mediation, peacebuilding processes and conflict prevention. It also aims at building the trust and interpersonal relationships required to support cooperation at every scale by identifying new opportunities for cooperation, and by improving approaches to multi-stakeholder cooperation and inclusion in transboundary water dialogues.

---

[34] For more information, please see: https://sdgs.un.org/partnerships/rising-tide-support-women-water-diplomacy.

7.4. Groundwater and transboundary aquifers

Groundwater is an important source of freshwater for people's daily needs and for development, and a large proportion of the world's freshwater resources are in transboundary aquifers (United Nations, 2022). Effective water governance and cooperation support the conjunctive management of both transboundary surface and groundwater resources. Such management should be underpinned by sound data. A transboundary diagnostic analysis (TDA), supported by a strategic action plan (SAP) involving a joint technical assessment, as well as joint monitoring and data-sharing, can bolster cooperation.

Box 7.1 Dinaric Karst Aquifer System

The Dinaric Karst Aquifer System (DIKTAS) is one of the world's largest karst aquifer systems spanning from Italy to Greece, across nearly ten countries in South-East Europe. Drinking water supply in the region heavily depends on this aquifer. However, the system and the services it provides are threatened by unsustainable uses. The system is highly vulnerable to pollution from inappropriate disposal of solid waste, untreated wastewater, and agricultural and industrial activities, due to the system's high permeability and limited self-purification capacity.

Under the project "Protection and Sustainable Use of the DIKTAS" involving Albania, Bosnia and Herzegovina, Croatia, and Montenegro, a transboundary diagnostic analysis (TDA) enhanced understanding of the aquifer system, including the main sources of pollution. Based on the evidence from the TDA, a Strategic Action Programme (SAP), a negotiated policy document, identified a number of policy, legal, institutional and investment actions. The project functioned through National Inter-Ministerial Committees (NICs) in each country, which allowed for the engagement and contribution of all related sectors. The NICs discussed and agreed upon the SAP. In addition to the NICs, the parties agreed to form a Regional Consultation and Information Exchange Body, composed of partner countries' senior government officials, as the first step to the commitment to transboundary cooperation.

The DIKTAS project contributed, through its activities, regular meetings and trainings, to trust-building and dialogues among countries, but also between actors within each country that did not usually meet. Reaching an agreement on the SAP can thus be considered a success and an important step forward in a post-conflict zone where peace needed to be rebuilt. Water cooperation provided one crucial pathway to do so. The second phase of DIKTAS (2023–2027) aims to build on the SAP, further strengthening regional collaboration and operationalizing earlier commitments.

In 2017, the Orange-Senqu River Commission (ORASECOM) Council, consisting of representatives from the respective government agencies responsible for water affairs from Botswana, Namibia and South Africa, endorsed a resolution to establish the Multi-Country Cooperation Mechanisms (MCCM) for the Stampriet Aquifer system. This embeds a groundwater-specific mechanism into a river basin organization, thus facilitating the conjunctive management of surface water groundwater resources, and building on already existing cooperation experience (Burchi, n.d.). This represents the outcome of a process initiated by joint assessment and data-sharing by the three countries, facilitated within a specific project (UNESCO, 2021).

The Shire River basin (shared between Malawi and Mozambique), a surface water catchment within the Zambezi River basin, overlays two transboundary aquifers. The basin population in both countries faces high poverty levels aggravated by vulnerability to floods and water quality degradation due to increased economic activity. A TDA identified deficient flood control, poor water quality, lack of data and monitoring, and insufficient cross-country coordination as central challenges. A subsequent SAP identified the following four objectives:

- *"Strengthen national and transboundary institutional cooperation to improve management for sustainable development and management of the basin and its shared aquifers.*
- *Improve the quality and quantity of data for improved conjunctive water development and management decision-making by instituting a joint monitoring system for data collection, sharing and standardization.*
- *Reduce the adverse impacts of climate variability and change (i.e. floods and droughts) through joint conjunctive management of surface water and groundwater, including the use of natural infrastructure (e.g., aquifers and wetlands) and implementation of early warning systems.*
- *Promote catchment management (e.g., reducing overexploitation, revitalizing natural vegetation) in order to enhance water quality, stream flow and groundwater retention/recharge"* (SADC-GMI/IWMI, 2019, p. iii).

Indigenous and traditional communities may have long-standing networks across borders

The TDA and its consequent SAP can form the first basis for initiating transboundary cooperation-based conjunctive management in a manner coherent with the existing Zambezi Watercourse Convention (The Republic of Angola/The Republic of Botswana/ The Republic of Malawi/The Republic of Mozambique/The Republic of Namibia/The United Republic of Tanzania/The Republic of Zambia/The Republic of Zimbabwe, 2004). Other ongoing initiatives in Southern Africa include the Tuli Karoo Transboundary Aquifer Area shared by Botswana, South Africa and Zimbabwe (Mowaneng et al., 2021).

Institutions like the Senegal River Basin Development Organization (OMVS) and the Gambia River Basin Development Organization (OMVG) could be instrumental in integrating transboundary aquifers in regional planning and development. In 2021, Gambia, Guinea-Bissau, Mauritania and Senegal signed a ministerial declaration on the Senegalo-Mauritanian Aquifer Basin (SMAB), which supplies an estimated 80% of the basin population with groundwater (UNECE, 2021). The declaration called upon the OMVG and the OMVS to elaborate on the future intergovernmental mechanism for concerted management of the SMAB. This would be the first such mechanism in West Africa.

7.5 Trends and conclusions

Appropriate legal and institutional arrangements need to be established or enhanced to deal with growing competition over transboundary water resources. With increasingly complex challenges over water access, quality and management and in order to prevent future disputes, flexible arrangements adaptable to changing pressures, particularly measures for climate change adaptation and mitigation, and inclusion of consultation and dispute settlement procedures, will be crucial. Advancing water cooperation and water diplomacy will require increasing capacity, at all levels, including for negotiating new agreements and joint bodies, strengthening existing ones, and addressing the linkages between water and other development objectives. It is a long process, requiring time and trust-building. Initiatives such as regional dialogues, or the involvement of non-traditional actors, such as local communities, can contribute substantially. Cooperation is not a linear process, as new challenges can arise at any time. In this regard, transboundary river, lake and aquifer basin organizations are crucial convening and negotiating forums, and serving as agents of peace.

The UN water conventions provide tools for supporting cooperation and agreements based on the fundamental principles of customary international law, complemented by the *Draft Articles on the Law of Transboundary Aquifers*.[35] Most of the practical benefits of the Water Convention derive from its institutional framework and activities at global, regional, national and transboundary levels, particularly under its triennial programme of work (UNECE, 2022). Since its adoption in 1992, 52 parties have acceded to the Water Convention,[36] enhancing prospects for conflict prevention and stability in several regions.

By acceding to and implementing the UN water conventions, as called for by the Secretary-General of the United Nations (2023), countries can help build political will and accelerate transboundary cooperation for achievement of the SDGs. However, addressing gaps, reinforcing existing provisions, and strengthening implementation at the regional, basin, sub-basin and national level remain crucial in order to achieve practical results on the ground.

---

[35] For more information, please see: https://legal.un.org/ilc/texts/instruments/english/draft_articles/8_5_2008.pdf.

[36] The Convention was originally negotiated as a regional framework for the pan-European region. Following an amendment procedure, since March 2016 all UN Member States can accede to it. Chad and Senegal have become the first African Parties in 2018. Then, Ghana acceded in 2020 and was followed by Guinea-Bissau and Togo in 2021, by Cameroon in 2022, and Nigeria and The Gambia in 2023. Iraq acceded in March 2023 as the first country from the Middle East, Namibia in June 2023 as the first country from Southern Africa and Panama in July 2023 as the first country from Latin America.

Ultimately, political will is crucial for advancing transboundary water cooperation. Water's capacity to unite in transboundary contexts has been demonstrated over time to contribute to peace, sustainable development, climate action and regional integration, as exemplified above by efforts in the Sava and Senegal river basins. While reporting on SDG Indicator 6.5.2 indicates that numerous countries have demonstrated an ability to collaborate based on international water law principles and through joint institutions, the 2021 reporting results underline that transboundary water cooperation is needed more than ever as a cross-cutting enabler for peace, water security and shared prosperity (UNECE/UNESCO, 2021).

References

Auclair, A. and Lasserre, F. 2013. Aménagements, politiques et conflits sur l'eau en Afrique de l'Ouest [Political arrangements and conflicts over water in West Africa]. *Vertigo*, Vol. 13, No.2. doi.org/10.4000/vertigo.13994. (In French.)

Bosnia and Herzegovina/Republic of Croatia/Republic of Slovenia/Federal Republic of Yugoslavia. 2002. *Framework Agreement on the Sava River Basin*. www.fao.org/faolex/results/details/en/c/LEX-FAOC045452/.

Burchi, S. 2018. Legal frameworks for the governance of international transboundary aquifers: Pre- and post-ISARM experience. *Journal of Hydrology: Regional Studies*, Vol. 20, pp. 15–20. doi.org/10.1016/j.ejrh.2018.04.007.

_____. n.d. Botswana, Namibia and South Africa Develop Joint Governance Mechanism for the Stampriet Aquifer System in the Orange-Senqu River Commission. International Water Law Project Blog. www.internationalwaterlaw.org/blog/2019/12/09/botswana-namibia-and-south-africa-develop-joint-governance-mechanism-for-the-stampriet-aquifer-system-in-the-orange-senqu-river-commission/.

Cameroon/Chad/Niger/Nigeria. 1964. Convention and statutes relating to the development of the Chad basin. Signed at Fort Lamy, on 22 May 1964. *Journal Officiel de la République Fédérale du Cameroun*, 15 September 1964. www.fao.org/3/w7414b/w7414b05.htm.

Denoon, R. T. P., Paisley, R. K., De Chaisemartin, M. and Henshaw, T. W. 2020. Engaging non-state actors in the negotiation and implementation of international watercourse agreements: Experiences and lessons learned from Canada. *Water International*, Vol. 45, No. 4, pp. 311–328, doi.org/10.1080/02508060.2020.1734757.

Fauconnier, I., Jenniskens, A., Perry, P., Fanaian, S., Sen, S., Sinha, V. and Witmer, L. 2018. *Women as Change-Makers in the Governance of Shared Waters*. Gland, Switzerland, International Union for Conservation of Nature (IUCN). https://portals.iucn.org/library/sites/library/files/documents/2018-036-En.pdf.

General Assembly of the United Nations/Security Council. 1995. *General Framework Agreement for Peace in Bosnia and Herzegovina*. A/50/79C, S/1995/999, 30 November 1995. https://peacemaker.un.org/bosniadaytonagreement95.

Global High-Level Panel on Water and Peace. 2017. *A Matter of Survival (Report)*. Geneva, Geneva Water Hub. www.genevawaterhub.org/resource/matter-survival.

IGRAC (International Groundwater Resources Assessment Centre) 2021. Transboundary Aquifers of the World [map] Scale 1 : 50 000 000. Delft, the Netherlands, IGRAC. www.un-igrac.org/resource/transboundary-aquifers-world-map-2021.

ILC (International Law Commission). 2008. *Draft articles on the Law of Transboundary Aquifers*. United Nations. https://legal.un.org/ilc/texts/instruments/english/draft_articles/8_5_2008.pdf.

IUCN (International Union for Nature Conservancy). n.d. *Operationalising IWRM through Multi-Level Cooperation and Benefit-Sharing in the Meghna River Basin (Bangladesh and India)*. IUCN. www.iucn.org/sites/default/files/2022-07/meghna_basin_dialogue_and_work_plan_2022_ver_15_march_2022_0.pdf.

LCBC (Lake Chad Basin Commission). 2011. *Water Charter of the Lake Chad Basin*, 8 April 2011. LCBC. www.fao.org/faolex/results/details/en/c/LEX-FAOC203691/#:~:text=This%20Water%20Charter%20is%20an,of%20the%20Lake%20Chad%20Basin.

McCracken, M. and Wolf, A. T. 2019. Updating the register of international river basins of the world. *International Journal of Water Resources Development*, Vol. 35, No. 5, pp. 732–782. doi.org/10.1080/07900627.2019.1572497.

Mirumachi, N. 2020. Informal water diplomacy and power: A case of seeking water security in the Mekong River basin. *Environmental Science and Policy*, Vol. 114, pp. 86–95. doi.org/10.1016/j.envsci.2020.07.021.

Mowaneng, P. S., Kenabatho, P., Ebrahim, G. Y., Lautze, J. and Pavelic, P. 2021. *GIS Based Multi-Criteria Decision Analysis to Assess Managed Aquifer Recharge Potential in the Tuli-Karoo Transboundary Aquifer*. Pretoria, International Water Management Institute (IWMI). https://conjunctivecooperation.iwmi.org/wp-content/uploads/sites/38/2021/03/MARSuitabilityTuliKarooFINAL.pdf.

OSU (Oregon State University). n.d. International River Basin Organization (RBO) Database. Program in Water Conflict Management and Transformation. OSU website. https://transboundarywaters.science.oregonstate.edu/content/international-river-basin-organization-rbo-database.

Petersen-Perlman, J. D., Veilleux, J. C. and Wolf, A. T. 2017. International water conflict and cooperation: Challenges and opportunities. *Water International*, Vol. 42, No. 2, pp. 105–120. doi.org/10.1080/02508060.2017.1276041.

SADC-GMI/IWMI (Southern African Development Community-Groundwater Management Institute/International Water Management Institute). 2019. *Strategic Action Plan for the Shire River Aquifer System*, April 2019. SADC-GMI/IWMI. https://sadc-gmi.org/wp-content/uploads/2020/05/ENG_ShireConWat-SAP-1-2.pdf.

Secretary-General of the United Nations. 2023. Secretary-General's Remarks at the United Nations Water Conference. 22 March 2023. United Nations website. www.un.org/sg/en/content/sg/speeches/2023-03-22/secretary-generals-remarks-the-united-nations-water-conference.

Sehring, J., Schmeier, S., Ter Horst, R., Offutt, A. and Sharipova, B. 2022. Diving into water diplomacy – Exploring the emergence of a concept. *Diplomatica*, Vol. 4, No. 2, pp. 200–221. doi.org/10.1163/25891774-bja10082.

Supreme State Audit Office of Cameroon/Court of Accounts Chad/Court of Accounts Niger/Office of the Auditor-General for the Federation of Niger. 2015. *Joint Environmental Audit on the Drying up of Lake Chad*. Joint Audit Report. South Africa, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. www.giz.de/de/downloads/giz2015-en-joint-environmental-audit-report-lake-chad.pdf.

The Republic of Angola/The Republic of Botswana/The Republic of Malawi/The Republic of Mozambique/The Republic of Namibia/The United Republic of Tanzania/The Republic of Zambia/The Republic of Zimbabwe. 2004. *Agreement on the Establishment of the Zambezi Watercourse Commission*. www.fao.org/faolex/results/details/en/c/LEX-FAOC180628/.

UNDP (United Nations Development Programme). 2022. *Conflict Analysis in the Lake Chad Basin 2020–2021: Trends, Developments and Implications for Peace and Stability*. N'Djamena, UNDP Regional Hub West and Central Africa. www.undp.org/africa/publications/conflict-analysis-lake-chad-basin#:~:text=For%20decades%2C%20Lake%20Chad%20Basin,remain%20the%20Boko%20Haram%20crisis.

UNDP/GEF (United Nations Development Programme/Global Environment Facility). 2011. *International Waters: Review of Legal and Institutional Frameworks*. UNDP-GEF International Waters Project. http://content-ext.undp.org/aplaws_publications/3247154/IW_Review_of_Legal_Instl_Frameworks_Project_Report.pdf.

UNECE (United Nations Economic Commission for Europe). 2013. *Convention on the Protection and Use of Transboundary Watercourses and International Lakes*. As Amended, along with Decision VI/3 Clarifying the Accession Procedure. New York/Geneva, United Nations. unece.org/DAM/env/water/publications/WAT_Text/ECE_MP.WAT_41.pdf.

_____. 2021. The Gambia, Guinea Bissau, Mauritania and Senegal Commit to Cooperate on Shared Groundwater as Foundation for Regional Stability, Sustainable Development and Climate Adaptation. Press release, 29 September 2021. UNECE website. https://unece.org/climate-change/press/gambia-guinea-bissau-mauritania-and-senegal-commit-cooperate-shared.

_____. 2022. *The Water Convention: 30 Years of Impact and Achievements on the Ground*. Geneva, United Nations. https://unece.org/sites/default/files/2022-10/2210819_E_ECE_Version%20web%20corrig%C3%A9e_1.pdf.

UNECE/UNESCO (United Nations Economic Commission for Europe/United Nations Educational, Scientific and Cultural Organization). 2021. *Progress on Transboundary Water Cooperation: Global Status of SDG Indicator 6.5.2 and Acceleration Needs 2021*. Paris/Geneva, UNESCO/United Nations. unesdoc.unesco.org/ark:/48223/pf0000378914?posInSet=1&queryId=957ce00a-0462-4bab-8d10-8c5307999dee.

UNEP/OSU/FAO (United Nations Environment Programme/Oregon State University/Food and Agriculture Organization of the United Nations). 2002. *Atlas of International Freshwater Agreements*. Nairobi, UNEP. https://wedocs.unep.org/20.500.11822/8182.

UNESCO (United Nations Educational, Scientific and Cultural Organization). 2021. *ISARM 2021, 2nd International Conference: Transboundary Aquifers: Challenges and the Way Forward*. Book of Abstracts. Paris, UNESCO. https://unesdoc.unesco.org/ark:/48223/pf0000380029.locale=fr.

United Nations. 1997. *Convention on the Law of Non-Navigational Uses of International Watercourses*. New York, 21 May 1997. treaties.un.org/Pages/ViewDetails.aspx?src=IND&mtdsg_no=XXVII-12&chapter=27&clang=_en.

_____. 2001. *Agreement on Succession Issues*. https://treaties.un.org/Pages/ViewDetails.aspx?chapter=29&clang=_en&mtdsg_no=XXIX-1&src=TREATY.

_____. 2022. *The United Nations World Water Development Report 2022: Groundwater: Making the Invisible Visible*. Paris, United Nations Educational, Scientific and Cultural Organization (UNESCO). https://unesdoc.unesco.org/ark:/48223/pf0000380721.

_____. 2023. *2023 United Nations Conference on the Midterm Comprehensive Review of the Implementation of the Objectives of the International Decade for Action, "Water for Sustainable Development", 2018–2028*. New York, 22 March –24 March 2023. Interactive Dialogue 4: Water for Cooperation. https://sdgs.un.org/sites/default/files/2023-01/23-00148%20Concept%20Paper%20UNWC_ID4_Website.pdf.

Chapter 8

Regional perspectives

8.1 Sub-Saharan Africa

WWAP
Matthew England and Richard Connor

UNESCO Nairobi Office
Alexandros Makarigakis, Christian Berretta and Seifu Kebede

8.2 Europe and North America

UNECE
Sonja Koeppel, Remy Kinna, Lucia De Strasser and Elise Zerrath

8.3 Latin America and the Caribbean

UNECLAC
Silvia Saravia Matus, Lisbeth Naranjo, Natalia Sarmanto, Alba Llavona and Elisa Blanco

With contributions from: Miguel Doria, Camila Tori and Ricardo Burg (UNESCO Montevideo Office)

8.4 Asia and the Pacific

ESCAP
Kyungkoo Philip Kang, Aneta Nikolova and Anshuman Varma

With contributions from: Marisha Wojciechowska and Caroline Turner (ESCAP)

8.5 Arab region

UNESCWA
Ziad Khayat, Sara Hess and Tracy Zaarour

8.1 Sub-Saharan Africa

Population growth, rapid urbanization, changing lifestyles and consumption patterns, along with economic development, are increasing water demand throughout Sub-Saharan Africa. At the same time, water quality is severely deteriorating. Agriculture, accounting for an estimated 79% of total water withdrawal across the region (AQUASTAT, n.d.), generates an estimated 25% of Africa's gross domestic product (GDP); engaging the livelihoods of an estimated 60% of the population, the majority of which are smallholder farmers (FAO, 2020; 2021; AMCOW, 2012). Demand for domestic supply – currently around 13% of total water withdrawal (AQUASTAT, n.d.) – is rising sharply in urban centres and peri-urban areas, creating major challenges for service providers, with informal settlements remaining acutely underserved (Dos Santos et al., 2017). Critical as a catalyst for economic diversification, industrial development accounts for an estimated 7% of total water withdrawal (AQUASTAT, n.d.), and this figure is predicted to significantly rise in future years (Boretti and Rosa, 2019; AMCOW, 2012).

While surface water resources are unevenly distributed, groundwater is relatively abundant throughout most of the region (Figure 8.1) (United Nations, 2022). Most of Sub-Saharan Africa suffers from economic water scarcity, characterized not by the relative level of availability of water resources, but by the lack of appropriate infrastructure, as well as inadequate management and insufficient economic resources and incentives. All these factors hinder lasting progress[37] (UNECA/AU/AfDB, 2003). Notably, there is significant potential for further hydroelectricity generation in the region (IEA, 2022).

Most of Sub-Saharan Africa suffers from economic water scarcity

Over a third of the countries in Africa – with a combined population of over half a billion (out of a total 1.3 billion) – are considered 'water-insecure' (MacAlister et al., 2023; Oluwasanya et al., 2022). This mirrors Africa's progress towards the Sustainable Development Goals (SDGs), which has been slow according to most indicators, even regressing in some cases (UN-Water, n.d.). For instance, since 2015, the number of people without safely managed drinking water in Africa has increased from 703 to 766 million (UN-Water, 2021), despite the fact that Africa receives one third of global official development assistance for the water sector.[38] Capacity to monitor SDG data indicators is generally inadequate, in spite of high-level calls and long-term global efforts to improve data availability (UNECE/UNESCO, 2018). Climate change exacerbates water insecurity through temperature rise and increasing temporal and spatial precipitation variability, and impacts water availability through soil moisture and runoff (IPCC, 2022).

Factors hindering the prospects for prosperity and peace include: weak institutional arrangements and legal frameworks; insufficient financial arrangements; inadequate data and human capacity; low levels of public awareness and stakeholders participation; and inadequate infrastructure for delivering water for irrigation, domestic and industrial requirements (MacAlister et al., 2023; Oluwasanya et al., 2022; UN-Water, 2021; UNECA/AU/AfDB, 2003; Van Koppen, 2003).

8.1.1 Transboundary water cooperation

The vast majority (42 out of 48) of countries in Sub-Saharan Africa share a transboundary basin in the form of rivers, lakes and groundwater aquifers[39] (UNECE/UNESCO, 2018). Africa has the highest proportion of transboundary basins relative to other continents, covering an estimated 64% of the land area (UNECA, 2021).

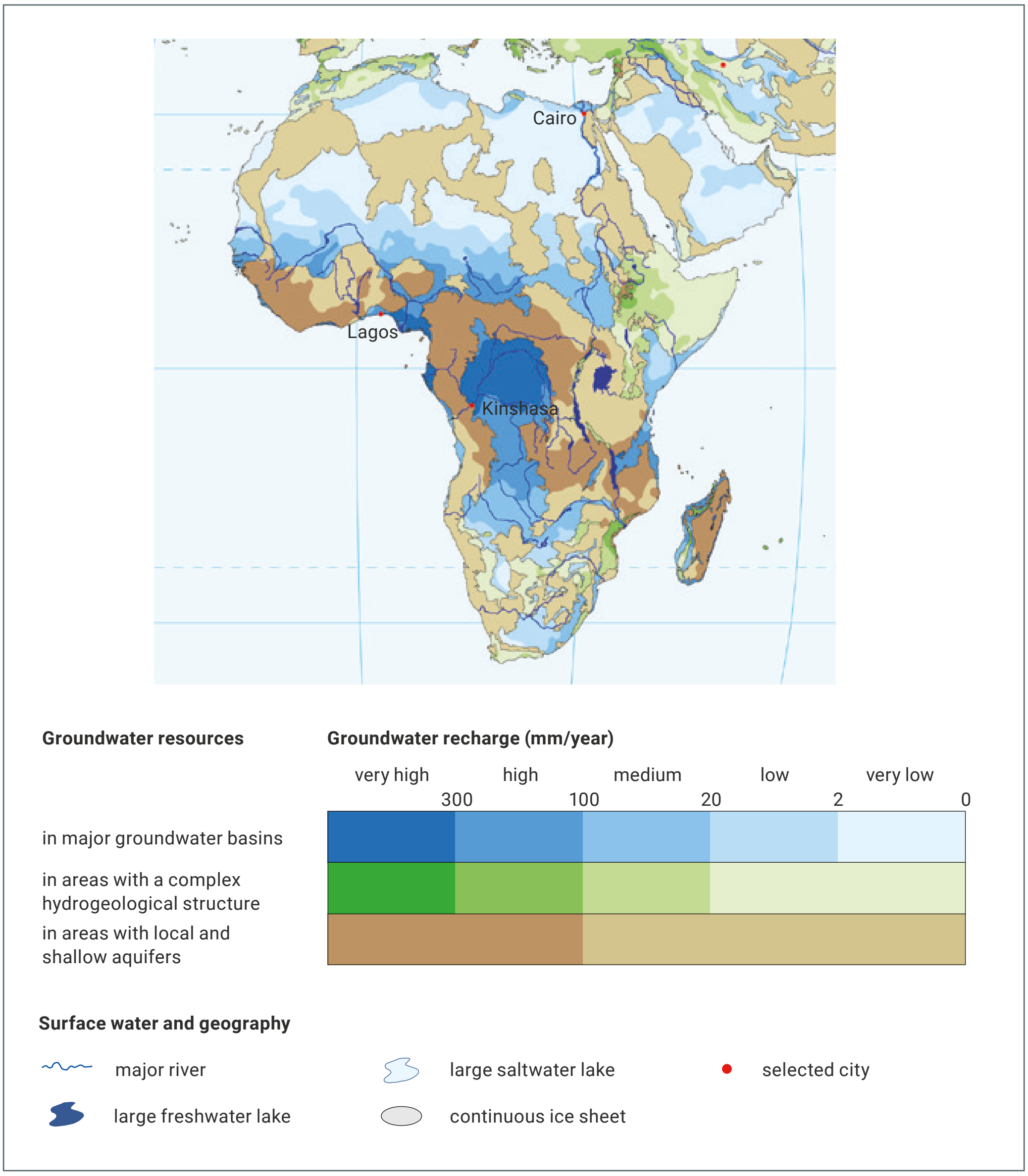
---

[37] Exceptions include South Africa where all physically available water resources have largely been developed, and where physical water scarcity prevails (Van Koppen, 2003).

[38] Financial disbursements to Africa increased from US$2.4 billion in 2015 to US$3.0 billion in 2019, including an increase of 58% in aid to large water and sanitation systems and a 12% increase in aid for water sector policy and administrative management (UN-Water, 2021).

[39] A transboundary basin refers to a river or lake basin, or an aquifer system that mark, cross or is located on boundaries between two or more states. A basin comprises the entire catchment area of a surface water body (river or lake); or, for groundwater, the area of the aquifer (UNECE/UNESCO, 2018).

Figure 8.1
Groundwater resources of Africa



Adapted from BGR/UNESCO (2008).

Africa has the highest proportion of transboundary basins relative to other continents

Transboundary basins, including surface and groundwater, create 'water interdependencies' across the territories through which they span and/or travel. Disparate national policies and legal frameworks can create barriers for coherent management of these hydrological systems. Overcoming such barriers requires cooperative state interaction, through which nations coordinate interventions for mutual benefit (Frey, 1993). In the absence of a supranational authority, states may address these barriers by negotiating rules and procedures to govern and regulate the management of transboundary waters, including groundwater (UNECA, 2021).

Near the beginning or the millennium, the Africa Water Vision for 2025 (UNECA/AU/AfDB, 2003) called for effective transboundary cooperation to enable equitable water allocation and sustainable use in Africa as a tool to strengthen regional economic growth and social integration. Transboundary cooperation in Africa includes operational arrangements such as shared agreements (Lautze and Giordano, 2005) and river basin organizations (Saruchera and Lautze, 2016). The mutual benefits to riparians include joint riparian water supply and hydroelectricity infrastructure projects promoting food and energy security; the potential for increased hydrological monitoring and data-sharing; and effective coordination and sector integration through river basin organizations (United Nations, 2023a; Sadoff and Grey, 2002).

The hydro-political history of Southern Africa is marked by a high number of international agreements and operational arrangements on shared waters (UNECA, 2021). Endeavours to promote transboundary cooperation were established through the instrumental South African Development Community protocol (SADC, 1995). This Protocol subsequently led to planning and execution of joint water projects, such as the Lesotho Highlands Project (Mirumachi, 2007). The Protocol was negotiated on the basis of equitable water-sharing, acting as a catalyst for wider political cooperation, economic integration and security in the region (Savenije and Van der Zaag, 2000). The Okavango River Basin Water Commission, established by Angola, Botswana and Namibia to jointly manage water resources of the Cubango-Okavango River basin, is another notable example (Green et al., 2013).

Similar institutional arrangements have also been established within West Africa. Basin-wide legal frameworks, supported by joint bodies and river basin organizations are in place for the major river basins including the Senegal, Gambia, Volta and Niger rivers. For instance, overseen by the Senegal River Development Organization, Senegal, Mali and Mauritania agreed to share the development costs and benefits of infrastructure jointly operated on the Senegal River (Dos Santos, 2023).

In Central Africa, cooperation has been organized by the Economic Community of Central African States. The International Commission of the Congo-Oubangui-Sangha Basin was established with a mandate focused on navigation (including trade), energy and other approaches based upon integrated water resources management (Medinilla, 2017). Other regional initiatives include the Lake Chad River Basin Commission[40] and the adoption of the Lake Chad Basin Water Charter (Galeazzi et al., 2017).

Agreements and operational arrangements over transboundary freshwater resources can help promote peace and stability

In East Africa, the Nile Basin Initiative was established in 1999, including a technical advisory committee and secretariat. The Initiative has played an important role in fostering cooperation, although challenges associated with implementing the Nile River Basin Cooperative Framework Agreement are recognized (UNECE/UNESCO, 2018).

8.1.2 Transboundary groundwater governance

Groundwater is a critical resource for supplies throughout Sub-Saharan Africa, particularly in arid and semi-arid areas during periods of drought (Figure 8.1) (MacDonald et al., 2012). Of the 72 transboundary aquifers mapped in Africa, underlying 40% of the land area, cooperation has been formalized in seven (Nijsten et al., 2018).

If transboundary aquifers are covered by international cooperation, this occurs primarily through surface water agreements (concerning rivers and lakes) (TWAP, n.d.). There have only been few reports of coordinated activities related to transboundary aquifer assessment, monitoring or management (Nijsten et al., 2018). The lack of groundwater data is a major contributing factor to uncoordinated reporting (Fraser et al., 2023). Increasing awareness and support of joint transboundary aquifer management is noticeable amongst international organizations. However, cooperation also requires long-term national commitment to produce impacts at the local level (Box 8.1) (Nijsten et al., 2018).

8.1.3 Way forward

Rising water scarcity in Sub-Saharan Africa poses significant water management challenges. Given the large proportion of transboundary basins in the region, mutual interests in transboundary cooperation – such as for water quality, water supply, infrastructure projects for agriculture and energy, flood control, and management of climate change impacts – can bring riparians and stakeholders together to collaboratively promote water, energy and food security. Transboundary cooperation can broaden the knowledge base, enlarge the range of measures available to mitigate water risk, increase preparedness and recovery for droughts and floods, and offer more cost-effective solutions (UNECA, 2021).

[40] Including Cameroon, the Central African Republic, Chad, Libya, Niger and Nigeria.

Box 8.1 The Governance of Groundwater Resources in Transboundary Aquifers (GGRETA) project

The Governance of Groundwater Resources in Transboundary Aquifers (GGRETA[a]) project has promoted transboundary cooperation with regards to the Stampriet aquifer system, located in a large arid region of Southern Africa shared by Botswana, Namibia and South Africa. In 2017, member states established a Multi-Country Cooperation Mechanism[b] for the Stampriet aquifer system, which was subsequently incorporated into the Orange-Senqu River Basin Commission represented by the Groundwater Hydrology Committee. This was the first example in Sub-Saharan Africa of integrating groundwater with surface water within a transboundary basin, thereby following principles of integrated water resources management and contributing to SDG Indicator 6.5.2. Similarly, the GICRESAIT project[c] in West Africa focused on the Iullemeden-Taoudeni-Tanezrouft aquifer systems[d] in relation to the Niger River, strengthening the riparians' approach to integrated surface water and aquifer management (UNECE/UNESCO, 2018). This project built upon already established transboundary coordination and cooperation through the African Network of Basin Organizations and the African Ministers' Council on Water (AMCOW).

a In partnership with UNESCO's Intergovernmental Hydrological Programme (IHP) and the International Groundwater Resources Assessment Centre (IGRAC). For more information, please see: https://en.unesco.org/ggreta.

b Functions include the monitoring, planning and execution of joint groundwater- focused projects in the Stampriet aquifer system.

c For more information, please see: www.oss-online.org/en/releases/OSS-GICRESAIT-Synthese.

d Algeria, Benin, Burkina Faso, Mali, Mauritania, Niger and Nigeria.

8.2 Europe and North America

Contemporary geo-political events have exposed the devastating consequences of armed conflict for natural resources, livelihoods, water infrastructure and security in parts of the region. The return of armed conflict to the European continent raises questions on how to foster cooperation, sustainable development and peace through water diplomacy.

This section will showcase examples demonstrating how water cooperation mechanisms in the region have contributed to increase water security, prosperity and peace. These positive examples are particularly relevant given the increasing pressures that climate change places on water resources.

North America has a long history of transboundary water cooperation. The International Boundary and Water Commission (IBWC)[41] was established in 1889 and is responsible for applying the boundary and water treaties between the United States and Mexico. The International Joint Commission (IJC)[42] was established under the 1909 Boundary Waters Treaty to prevent and resolve disputes between the United States of America and Canada and to pursue the common good of both countries as an independent and objective advisor to the two governments.

Such agreements and operational arrangements over transboundary freshwater resources can help promote peace and stability

With 27 out of 42 countries reporting that operational arrangements cover 90% or more of their transboundary river and lake basin area, the Pan-European region represents one of the most advanced regions globally in terms of transboundary water cooperation (UNECE/UNESCO, 2021, p. xii). Such agreements and operational arrangements over transboundary freshwater resources can help promote peace and stability.

The *Convention on the Protection and Use of Transboundary Watercourses and International Lakes* (Water Convention) is likely to have contributed to this achievement by strengthening regional integration and turning shared waters into a key driver for sustainable development and peace. One of the main provisions of the Convention is setting up operational basin-level agreements and basin organizations. Across the region, government-established transboundary river basin organizations can act as connectors and active peacemakers by

41 For more information, please see: www.ibwc.gov/.

42 For more information, please see: https://ijc.org/en.

facilitating inclusive dialogue and participatory decision-making. River basin organizations have established mechanisms for multi-stakeholder engagement, giving voice to young people, women and concerned stakeholders.[43] The first case study (Box 8.2) highlights how joint management of the Sava River, the Danube's longest tributary, helped build trust between former Yugoslav republics less than one decade after they had been at war.

Box 8.2 Post-war recovery: Benefits of transboundary cooperation in the Sava and Drina River basins

The collaborative management of the Sava River basin, shared by Bosnia and Herzegovina, Croatia, Montenegro, Serbia and Slovenia, exemplifies a 'best practice' in transboundary cooperation, resulting in an effective process of socio-economic recovery in the basin through post-conflict cooperation over water (The Economist Intelligence Unit, 2019). The value of this cooperation is still evident today, as countries are jointly tackling emerging issues (notably climate change adaptation, including drought management) and strengthen cross-sectoral cooperation for sustainable planning and policy development, including in the Drina River sub-basin where most of the basin's hydropower is concentrated.

The International Sava River Basin Commission (ISRBC) was established in 2002 with the mandate of implementing the Framework Agreement for the Sava River Basin (FASRB). Remarkably, this was the first regional agreement to be signed since the Dayton Peace Agreement ended the war in the former Yugoslavia. The restoration of inland navigation allowed the return of regional trade, strengthening economic integration across the countries and beyond, notably with the European Union. Rebuilding of bridges and ports throughout the basin accompanied the removal of war debris and mines, leading to the restoration of the local livelihoods, including agriculture and tourism.

In the context of increasing tensions between different major water users, such as agriculture and energy, a participatory assessment of the water–food–energy–ecosystems nexus under the Water Convention was carried out in the Sava[a] (2014) and later in the Drina[b] (2016–2022, through multiple projects) River basin areas. The aim of these assessments was to look for cross-sectoral solutions to increase resource use efficiency, capitalize on regional complementarities, and improve natural resource governance.

These efforts resulted, among others, in the quantification of the benefits of transboundary cooperation on hydropower and the elaboration of possible ways to operationalize flow regulation in the basin (also through the establishment of a dedicated expert group), as part of a 'nexus roadmap' for coordinating actions across sectors and countries. The roadmap aims to coherently guide policy-makers through the implementation of their sectoral and cross-sectoral strategic plans at the basin level (including notably through the Green Action Plan for the Western Balkans – GWP-Med, 2022; n.d.). Climate adaptation, sustainable renewable energy planning and sediment management are among the cross-sectoral activities included in the roadmap and also guide the "Sava and Drina Rivers Corridors Integrated Development Program".[c]

---

[a] More information on the approach can be found at: https://unece.org/environment-policy/water/areas-work-convention/water-food-energy-ecosystem-nexus.

[b] The Drina Nexus Assessment, along with the Nexus Roadmap and the 'project documents', available at Drina Nexus Assessment – GWP: www.gwp.org/en/GWP-Mediterranean/WE-ACT/Programmes-per-theme/Water-Food-Energy-Nexus/seenexus/drina/.

[c] For more information, please see: www.worldbank.org/en/news/loans-credits/2020/08/06/sava-and-drina-rivers-corridors-integrated-development-program.

---

[43] More information on the public participation efforts of the International Commission for the Protection of the Danube River (ICPDR) can be found here: www.icpdr.org/main/activities-projects/public-participation.

The second case study (Box 8.3) focuses on the establishment of regional institutions to reduce tensions and strengthen transboundary water cooperation in Central Asia, with the objective to foster social, economic and environmental prosperity in the region.

Box 8.3 Establishment of regional bodies to foster transboundary water cooperation in Central Asia

Shared management of rivers in Central Asia has been challenging due to the Aral Sea basin crisis, difficulties for upstream and downstream countries to agree on water release regimes and water distribution, competition between the energy and irrigation sectors, further deterioration of aquatic ecosystems, and climate change increasingly diminishing scarce water resources. Moreover, in downstream segments of major transboundary rivers such as the Syr Darya and Amu Darya, "*low quality of water has had serious negative health effects*" (UNECE, 2008, p. 4).

Several regional bodies were established in the early 1990s. In 1992, the Interstate Commission for Water Coordination of Central Asia (ICWC), composed of ministers responsible for water resources, was set up to agree on water allocation regimes. The following year, in 1993, the heads of state of Central Asian countries established the International Fund for Saving the Aral Sea (IFAS) as a regional mechanism for broader cooperation in the Aral Sea basin. For many years, IFAS and the ICWC have played important roles in reducing tensions over the management of shared waters. By creating a regional forum for interstate relations on transboundary water, Central Asian countries have managed to maintain relatively cooperative and peaceful relations despite ongoing water quality and quantity issues. Discussions on reforming the regional institutions with an aim to make the IFAS system better fit to respond to present and future challenges, including climate change, have been ongoing since 2009.

At the bilateral level, Central Asian water relations took a considerable step forward on 26 July 2006, when the Kazakh–Kyrgyz Chu and Talas Rivers Commission was inaugurated (UNECE, 2008, p. 3). The Chu–Talas Rivers Commission "*gives a mutually beneficial way for Kyrgyzstan and Kazakhstan to share the responsibility for water infrastructure used by both countries*" whereby "*as part of the bilateral agreement, Kazakhstan agreed to pay part of the operating and maintenance expenses for a number of Kyrgyz dams and reservoirs supplying water to both countries*" (UNECE, 2008, p. 3).

In the ensuing years, transboundary water management has gradually improved through investment in monitoring and data-sharing systems, basin-wide climate change adaptation strategies and improvements in institutional capacity on transboundary water governance. With pressure on water resources increasing, "*there is a need to improve the legal agreements to ensure they take into account the national and regional water and energy interests of the Central Asian countries*" (IWAC, 2021, p. 67). These agreements should be comprehensive in nature and "*designed to ensure a basis for sustainable cooperation between the Central Asian states, regulate water and energy relations and encourage the development of agreements in other areas of water resources management*" (IWAC, 2021, p. 67).

Transboundary water allocation has gained increasing attention and resulted in strategic efforts from national, regional and international stakeholders to improve capacity and practices in this regard. The International Water Assessment Centre based in Kazakhstan recently led a two-year regional process on sustainable water allocation for stronger transboundary water cooperation; the major output was a set of recommendations and case studies that were published and subsequently included in the global *Handbook on Water Allocation in a Transboundary Context* (UNECE, 2021). In November 2022, a regional capacity-building workshop in Central Asia followed, raising awareness about the need for all water users to work closely together to improve the implementation of integrated water resources management principles for continued advancements in shared peace and prosperity (Forbes Kazakhstan, 2022).

8.3 Latin America and the Caribbean

Various types of cooperation and coordination mechanisms have led to enhanced water security, sustainable development and peace in Latin America and the Caribbean. Experiences with transboundary water partnerships, area-based development processes and management of multipurpose dams in the region highlight challenges and lessons learned to reduce tensions among multiple water users.

8.3.1 Transboundary water-related partnerships

Access and control over natural resources are potential sources of transboundary tensions. Water is no exception, particularly in the context of increasingly varying weather and rainfall conditions. Below are two cases where transnational alliances and agreements led to peaceful and sustainable water resource management.[44]

The Trifinio Commission and its long-term planning

A technical cooperation agreement between El Salvador, Guatemala and Honduras was concluded in 1986, targeting sustainable transboundary natural resource management in the Trifinio region. Increasing cooperation led to an international treaty for implementing the Trifinio development plan, in which the region has been designated as an indivisible ecological unit (GIZ, n.d.). It is considered a successful case of cooperation, since the joint efforts of the three countries have resulted in trinational initiatives to reduce poverty and develop their economies while adapting to new challenges, such as the conservation and restoration of their environmental systems. One of the main achievements has been the placement of 970 km^2 of land under environmental protection, through the declaration of the Trifinio Fraternidad Cross-border Biosphere Reserve, a trinational committee and management plan for protecting local ecosystems (BCIE/PlanTrifinio, 2022).

In 2007, El Salvador initiated a Trinational Water Agenda, proposing a common approach for all three countries to promote integrated water resource management (IWRM). This agenda and the creation of various transboundary water committees (such as the Binational Community Committee of the Sumpul River (sub-basin between El Salvador and Honduras) and the Güija Lake Binational Inter-Institutional Committee between El Salvador and Guatemala) show that the region is constantly searching for tools and frameworks to jointly address water and sustainability challenges. Since the establishment of the Trifinio Plan almost four decades ago, no international lawsuits have been filed around the Trifinio transboundary waters, and issues are addressed as part of bilateral agendas, solving the countries' specific difficulties and problems (GWP, 2016).

La Joya and Cueva del Monte rural communities: Transboundary water cooperation with a local twist

To solve the lack of access to drinking water and electricity services for rural communities located on the border between El Salvador and Honduras, a hydroelectric plant was built and financed through a binational commission and the environmental and natural resource authorities of the respective countries. The project, officially launched in 2012, was developed with the direct participation of two neighbouring rural communities: La Joya in the municipality of Perqüin, El Salvador, and Cueva del Monte in Marcala, Honduras (SICA, 2014).

---

[44] Other transboundary cooperation agreements in the region at the basin or river level include: the Amazon Cooperation Treaty, the Treaty on the Rio de la Plata Basin and its Coordinating Intergovernmental Committee (CIC), the Sixaola River basin agreement between Costa Rica and Panama, and the Autonomous Binational Authority of the Lake Titicaca, among several others.

The hydroelectric plant provides electricity to 35 families in the Salvadoran community, and 50 families on the Honduran side. The families used to pay US$0.50 every time they needed to charge a cell phone and had to walk for two hours to connect to a conventional electricity distribution network. There are therefore substantial savings in terms of money and time regarding electricity access. In addition, this electricity is now used at the local water filtration systems (UNECLAC, 2023).

The communities have formed a joint transnational management board and are now directly in charge of collecting fees for the maintenance and operation of the hydroelectric plant. Given that the project was created with their involvement through capacity-building initiatives, the members are also involved in the technical tasks related to the operation of the hydroelectric plant, ultimately securing its sustainable management (UNECLAC, 2023).

8.3.2 Community participation in local water governance: The Dry Corridor of Central America

Access and control over natural resources are potential sources of transboundary tensions

The Dry Corridor, which stretches over El Salvador, Guatemala, Honduras and Nicaragua, is characterized by high vulnerability to the impacts of climate change, particularly in the form of long periods of drought combined with excessive rainfall and severe floods. As the region's economy is dominated by agriculture, the ability to mitigate and adapt to climate change is vital for food security, health, nutrition, economic opportunities and environmental resilience. Sustainable management and access to water were therefore very important for the promotion of peace and security in this particular area.

To advance better governance and management of water resources on a local level, the countries and localities have recognized the importance of active community participation in decision-making, which takes place through open consultations and in-person meetings. Various programmes[45] have been implemented to promote water security and cooperation by creating either public–private partnerships, community involvement and/or basin organizations.

The project "Alianza del Corredor Seco" aims to reduce extreme poverty and malnutrition in rural Honduras by promoting effective and sustainable management of water resources and basins, based on the commitment to create and strengthen local alliances that effectively empower communities and their local governments. Non-governmental organizations (NGOs), local governments, national agencies and communities participate in capacity-building sessions and decision-making processes, with particular emphasis on involving women and youth. As a result, up to 2020, five public–private partnerships were created to support ecosystem conservation activities, and 36,000 families benefited from improved water supply and restoration of the recharge area. The project showed that, although it is challenging, networking and creating synergies between national government agencies, local governments and local organizations is key to improving water management and governance for common well-being (Global Communities, 2021).

Similarly, the "Programa Gobernanza Hídrica Territorial en la Región del Golfo de Fonseca" has fostered cooperation through the creation of basin councils to strengthen governance processes and human rights, mitigating conflicts as well as natural and climatic risks, and promoting the sustainable management of natural resources (GWP Central America, 2021). The project established three basin organizations that function as spaces for dialogue and articulation in water management, creating opportunities for public–private agreements and for a peaceful management of disputes over water. In addition, five community consortia were created that actively participate in the governance of the Region of the Gulf of Fonseca (SDC, 2021).

[45] Proyecto de Seguridad Hídrica en el Corredor Seco de Honduras (INVEST-Honduras, 2020); Programa de Gobernanza Hídrica Territorial en la Región 13 Golfo de Fonseca (FDFA, n.d.); La Alianza para el Corredor Seco (Government of Honduras, 2015; GAFSP/INVEST-Honduras, 2021).

8.3.3 Cross-sectoral cooperation over multipurpose infrastructure

There are approximately 251 multipurpose dam projects in LAC with diverse uses of hydroelectricity, irrigation, urban supply and/or flood control.[46] This type of infrastructure necessarily implies an intersectoral articulation for their management and coordination between multiple actors. An adequate balance is necessary throughout their entire life cycle to avoid conflicts.

Although hydroelectric energy in LAC represents 45% of electricity (IEA, 2021), its production is threatened by extreme and varying hydrometeorological events and the growing tensions that arise across users of the basins where they operate. Also, agriculture represents more than 70% of the water use in LAC (UNECLAC, 2023). Therefore, a water–energy–food nexus approach to promote synergies and optimize results in different sectors is needed. Two experiences illustrate this point: the Misicuní multipurpose dam in the Plurinational State of Bolivia and the Baba multipurpose dam in Ecuador.

A water–energy–food nexus approach to promote synergies and optimize results in different sectors is needed

The idea of the Misicuní multipurpose dam, located in Cochabamba, in the Plurinational State of Bolivia, arose in the 1950s due to the profound scarcity of water for daily consumption in the city and the nearby towns, aggravated by demographic growth and increasing demands. Water scarcity was the root cause for numerous conflicts in the area, reaching a critical moment in the year 2000 with the so-called 'water war' (Salazar, 2011). The multipurpose dam also aims to satisfy the increase in hydroelectric demand at the national level, generating a change towards renewable energy sources. However, the dam project planning considered the different water uses of the system independently. For instance, the irrigation and drinking water components were under the supervision the Misicuní company, while the national electricity company managed the electrical component. Thus, the lack of common vision and mutual agreement among the actors involved were factors that prevented an adequate implementation of the project (Willaarts et al., 2021). Similarly, the Baba multipurpose dam, located in Ecuador, aims to respond to the energy deficit problem at the national level and reduce the damage caused by floods at the subnational level, while providing opportunities for the supply of irrigation. However, at the subnational level, its justification was not well articulated or accompanied by a consultation process, which caused strong rejection by local communities.

Willaarts et al. (2021) compare and analyse both cases, concluding that financial planning and political leadership for promoting this type of infrastructure are the two pillars for successful execution. Additionally, three main bottlenecks are identified:

1. Asymmetry in the financial planning of intersectoral projects. Sometimes, public financing is available for one component (e.g. hydroelectric development), but other components have decentralized funding (e.g. irrigation, drinking water), with no capacity to finance the corresponding other parts.

2. High costs of public investment and social resistance to paying for the cost of service provision (e.g. potable water in the case of the Misicuní Dam).

3. The lack of planning in the medium and long term.

[46] In South America, the number of multipurpose projects corresponds to 169, with Argentina, Brazil, Colombia and Peru accounting for 76% (129 projects). In Central America and the Caribbean, 82 projects have been identified. The majority of them (74% – 61 projects) are located in Costa Rica, the Dominican Republic, Guatemala and Panama (AQUASTAT, n.d.).

Strong governance models, based on a water–energy–food nexus approach, connecting the different actors with a multilevel scope, are crucial when promoting intersectoral initiatives and looking for innovative formulas for their financing, especially if there is a vision to encourage joint investments to achieve the highest social benefit. Lack of these ingredients can lead to social unrest and unsustainable water management.

Financial planning and political leadership for promoting this type of infrastructure are the two pillars for successful execution

8.3.4 Conclusions

Experiences show that cooperation is needed to create trust and maintain peace. The regional examples showcase water cooperation at various levels, from community involvement and municipal collaboration programmes, all the way to national cooperation plans. It also highlights some of the limitations that can prevent the achievement of desired outcomes, such as a lack of coordination and involvement of various stakeholders. Additionally, a fundamental element for the advancement of peace and cooperation in water management involves not only strengthening of knowledge management, recognition of valuable ancestral practices as well as new technologies, but also enhanced regulatory and incentive systems aligned to the achievement of SDG 6 targets. The Latin American and Caribbean region has many transnational river basins and aquifers, as well as several multipurpose dams in which partnerships for more sustainable water use are vital for food, energy and water security. The latter are an essential contribution towards socio-economic development, climate resilience and prosperity.

8.4 Asia and the Pacific

8.4.1 Background on water situation

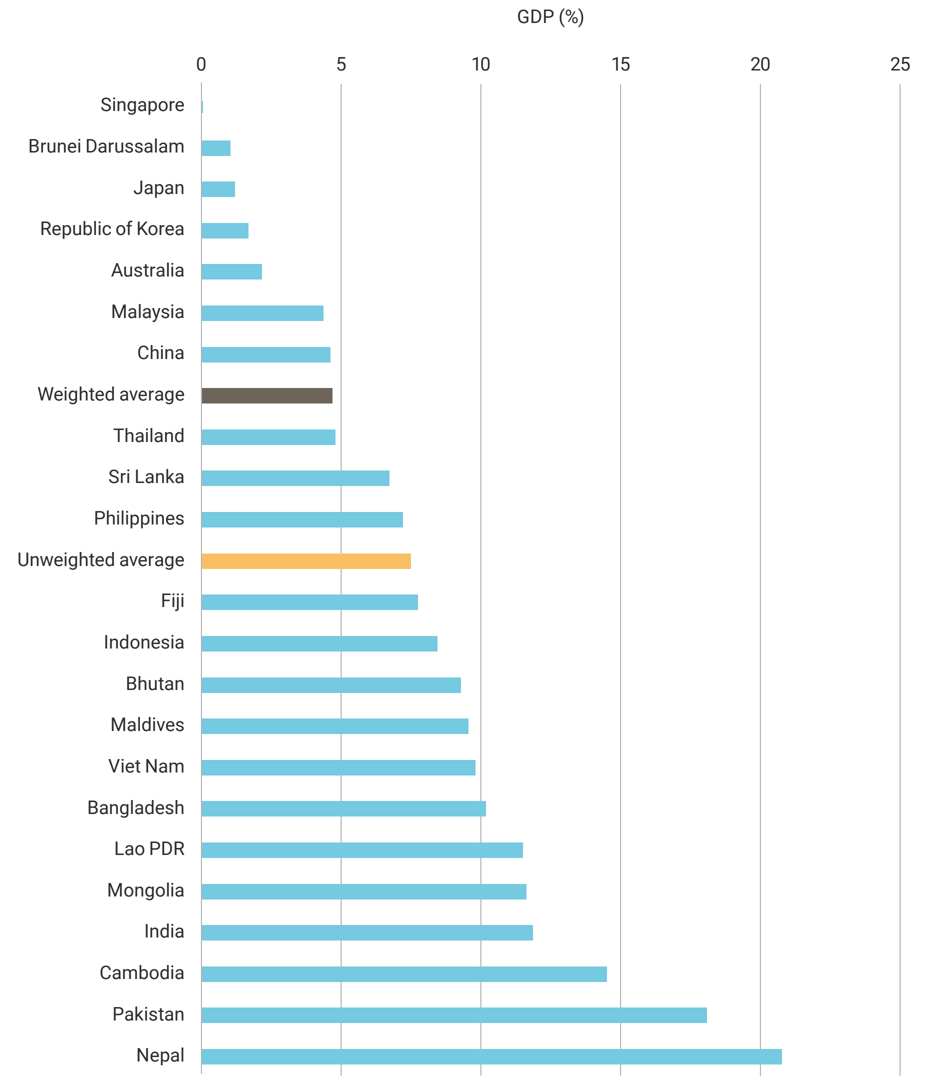
The Asia–Pacific region is home to only 36% of the world's water resources (ESCAP, 2021) and about 60% of the world population (United Nations, 2023b), making its per capita water availability the lowest in the world. To compound this fact, overconsumption of water resources was deemed to be the leading cause of water scarcity in the region (ESCAP, 2023b). In terms of peace and security, the interconnected reality of the vast river systems makes this region highly vulnerable to tensions or disagreements over water resources.

Water resources have been instrumental in the Asia–Pacific region's considerable improvement in economic and social welfare over the last decade, through water and sanitation hygiene (WASH), provision of basic services, agricultural expansion, food security and nutrition, and ecosystem services. However, the Asia–Pacific region is currently not on track to achieve any of the SDG 6 targets by 2030, as progress falls drastically short of where the region should have been by 2022 (ESCAP, 2023a). Large populations of the Asia–Pacific region still lack access to WASH services, especially in rural contexts, and water pollution has worsened in many of the region's most important river basins. Of the top-10 rivers in the world contributing to marine plastic occurrence, eight are located within Asia (Schmidt et al., 2017). Wetlands remain threatened by land conversion, many areas suffer from recurring water stress, and several countries continue to withdraw unsustainable amounts of freshwater (WWAP, 2019). Increasing water scarcity (SDG Target 6.4) is the foremost issue facing water resources and freshwater ecosystems in the Asia–Pacific region today (ESCAP, 2022). These multiple and complex water challenges are projected to intensify in the future, which will likely hinder economic development, threaten food and energy security, and damage valuable ecosystems (Wiberg et al., 2017).

Agriculture accounts for 80% of all freshwater use in the Asia–Pacific region (ADB, 2016), putting pressure on local hydrological systems in many areas (FAO/AWP, 2023). Asia's irrigation-dependent food baskets in Northwest India and North China are two of the world's top-three hotspots in terms of water-related risks to food production (OECD, 2017). As water scarcity becomes more prevalent in the Asia–Pacific region, governments will be tasked with the difficult challenge of prioritizing water uses across competing water-using sectors.

The agriculture sector employs 563 million people in the Asia–Pacific region, making up 30% of total employment (ILO, 2022a). In less developed economies, agriculture represents the highest share of GDP. This is the case, for example, in Nepal (21%), Pakistan (18%) and Cambodia (14.5%), with poverty rates more pronounced in rural areas (Figure 8.2). Consequently, increasing water scarcity or water events such as floods and droughts are more likely to directly impact less developed economies and vulnerable populations in the region, exacerbating existing vulnerabilities associated with low development outcomes, and threatening peace and security at a national level.

Figure 8.2
Agriculture's share of GDP (available Asian countries), 2020



Note:
The average of 22 countries in Asia are shown with and without population weighting.

Source: Based on ILO (2022b, fig. 1, p. 2).

Currently, countries in the region that experience high-water stress[47] include Afghanistan, Armenia, Kyrgyzstan, Nepal, Türkiye and Uzbekistan. Extremely high-water stress is experienced in India, Iran, Pakistan and Turkmenistan, among others (Hofste et al., 2019). While there is wide scientific recognition of increasing water scarcity, data on water withdrawals in the Asia–Pacific region are extremely limited as most water abstraction is not monitored (WWAP, 2019). The region's population living under high or extremely high water scarcity grew from 1.1 billion to over 2.6 billion between 1975 and 2010 (FAO/AWP, 2023).

[47] Baseline water stress measures the ratio of total water withdrawals to available renewable surface and groundwater supplies. Water stress is classified as follows: Low (0–1): <10%, Low to medium (1-2): 10–20%, Medium to high (2–3): 20–40%, High (3–4): 40–80%, Extremely high (4–5): >80% (Hofste et al., 2019).

Box 8.4 Capacity-building needs in Pacific Island countries

A significant push for increasing water sector capacities will be required to achieve SDG 6 targets in the Pacific. Only 60% of Pacific Islanders have access to basic drinking water and a mere 33% to basic sanitation, with the latter being the lowest rate recorded in the world (UNICEF, 2022). In addition to various governance, poor policy, legislation and ownership issues, a substantial gap in human capacity is also reported. Due to a lack of human capacity in water resource management, existing facilities are not operationally optimized, and an estimated 1,000 out of 8,500 employees in the sector require training on a yearly basis. This finding illustrates the human and financial resource constraints faced by the Pacific Island countries. A perception survey carried out in the Nadi catchment in Fiji found that Pacific Islanders employ traditional community-based approaches to manage water resources. With further training and the right tools, community managers can strengthen existing water resource management (Wilson et al., 2022).

As the world's most vulnerable region to disasters caused by natural hazards, climate change in the Asia–Pacific is compounding water scarcity and existing shortcomings in disaster response. Asia accounts for nearly one third (31%) of weather-, climate- and water-related disasters reported globally, for nearly half (47%) of deaths, and nearly one third (31%) of associated economic losses (WMO, 2021). Flood risks could exceed 6% of GDP in 2030 under a business-as-usual scenario in Afghanistan, Bangladesh, Cambodia, Kyrgyzstan, Tajikistan and Viet Nam, with all countries experiencing significant incidences of land subsidence. Further, coastal flood risks are projected to strongly affect the GDP of Bangladesh, the Solomon Islands, Vanuatu and Viet Nam (Leckie et al., 2021). Floods threaten agricultural production and economic activity, and can be expected to incite forced migration.

Pacific Islands also experience water scarcity and significant (often unique) impacts from changes in climate. Even where freshwater is relatively abundant, saltwater intrusion due to rising sea levels continually threatens the available freshwater supply, which makes enhancing resilience to climate change one of their most important development priorities. Further, local and institutional capacity to manage water resources is significantly lower compared to the greater Asian region. Due to the lack of training resources and appropriate capacities to address the unique challenges of the Pacific Islands, best practice water resource management is often difficult to implement (Box 8.4).

8.4.2 Transboundary cooperation

Asia is home to 57 transboundary river basins (UNEP/OSU/FAO, 2002), which account for 39% of the continent's land surface (Prabhakar et al., 2018). This makes the management of, and cooperation for, shared water resources a leading priority for prosperity and peace in the region, especially with the onslaught of hydrological system changes forecast as a result of the changing climate.

Historically, transboundary aquifers have received less political attention than rivers, due to their hidden, diverse nature, and the difficulty in conducting hydrological investigations across international borders. As a result, there are significant gaps in water policy and agreements for transboundary aquifers. A global inventory of transboundary aquifers identified 129 shared aquifers in Asia, measuring approximately 9 million km^2, covering about 20% of the entire region. Uzbekistan shares the most transboundary aquifers (total number: 31), followed by China (21), the Russian Federation (21), Tajikistan (15), Kazakhstan (14), Kyrgyzstan (14), Mongolia (14), Azerbaijan (13) and Iran (10) (Lee et al., 2018). Twelve 'significant' transboundary aquifers are shown in Figure 8.3.

Currently, over 80% of the countries in the Asia–Pacific region have established a river basin organization to manage water at some scale. However, less than 1% of countries have carried out stakeholder mapping and only one third of countries surveyed have implemented formal or informal mechanisms to engage stakeholders on water-related topics (OECD, 2021). Moreover, only 20% of the countries with river basin organizations have included provisions to protect indigenous and traditional rights (Leckie et al., 2021). This is a clear shortcoming in the region, and more efforts, such as the South Asia Water Initiative (Box 8.5), are required to promote inclusion.

Box 8.5 South Asia Water Initiative (SAWI)

The South Asia Water Initiative (SAWI) was a trust fund whose primary mission was to strengthen regional cooperation concerning the major Himalayan river systems and to promote climate resilience. Before it was closed in 2021, SAWI made significant strides in raising awareness about regional water issues for over a decade, augmenting technical and policy-making capabilities, advocating for inclusive dialogues and decision-making processes, and informing the World Bank's investment strategies in the water sector. It had a particular focus on the Indus, Ganges and Brahmaputra River basins, as well as the Sundarbans wetlands shared by Bangladesh and India. Its influence spanned seven countries: Afghanistan, Bangladesh, Bhutan, China, India, Nepal and Pakistan. Apart from its localized efforts in these basins and wetlands, SAWI undertook comprehensive regional initiatives to enhance knowledge, boost capacity, and foster dialogue and cooperation across borders. Improving the quality and accessibility of regional water resources datasets was central to its strategy. SAWI played a pivotal role in the dissemination of shared water management knowledge, facilitating regional dialogues to build trust and enhancing transboundary water collaboration in South Asia.

Source: World Bank (n.d.).

As another example, the Mekong River Commission (MRC) is unique in the region as a longstanding forum for transboundary river basin management. It was established as an independent body in 1995, following joint action facilitated by the United Nations starting in 1957. In April 2023, the South-East Asian members of the MRC (Cambodia, the Lao People's Democratic Republic, Thailand and Viet Nam) issued the new Vientiane Declaration, calling for intensified cooperation among governments, development partners and stakeholders. Among other statements of priority, the Vientiane Declaration emphasizes the role of the treaty-based forum as a regional knowledge hub. The website of the MRC provides public access to data for river monitoring and forecasting, and regularly hosts regional stakeholder forums; the latest forum focused on data-sharing for transparency and trust (MRC, n.d.).

8.4.3 Conclusions

The Asia–Pacific will face challenges in managing a future under conditions of water scarcity and a changing climate. At the same time, the region has tremendous opportunity to build upon the progress that has been achieved, especially by ensuring protection of water-related ecosystems and pursuing integrated solutions that can create synergies with climate goals. Developing a shared vision from local to transboundary levels for water management within and across basins, informed by rights-based approaches and gender-responsive principles and standards, would also realize rich dividends. National and regional cooperation and collaboration on water management is required to address climate risks and promote transboundary cooperation in order to support prosperity, security, and stability across the region.

8.5 Arab region

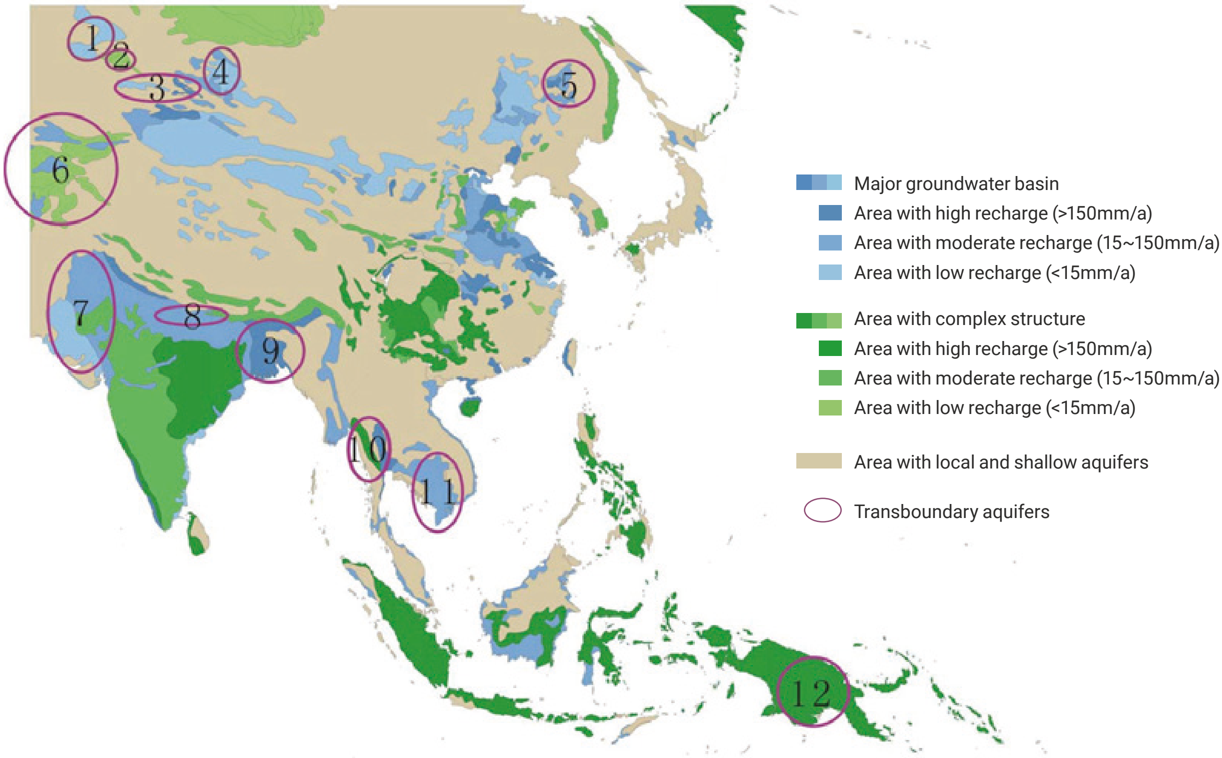
8.5.1 Regional setting

Cooperation on water at all levels, including transboundary and cross-sectoral, is of crucial importance to the Arab region, one of the most water-scarce regions in the world, with 19 of the 22 states below the water scarcity threshold.[48] Two thirds of the freshwater resources in the region are transboundary, and the 43 transboundary aquifers cover 58% of the area of the region (UNESCWA, 2022a). The challenges to fostering this cooperation include lack of data on water resources (especially groundwater) and competing demands for limited water resources among riparian states. The impacts of climate change are being felt acutely through increased water scarcity, which drives competition for this important natural resource. Further, the Arab region is strongly impacted by conflict. In 2021, seven Arab countries were in conflict, including protracted conflict with wide-ranging implications for water supply and infrastructure and for potential cooperation on water-related issues (UNESCWA, 2023). Nevertheless, there are several examples of how national and transboundary cooperation in the Arab region has contributed to greater water security, peace and prosperity.

---

[48] *"Scarcity classification is based on the Falkenmark water scarcity index for total annual renewable water resources per capita for the year. Three basic thresholds were identified; conditions of water stress for values below 1,700 m^3 per person per year; scarcity for values below 1,000 m^3 per person per year; and absolute scarcity for values below 500 m^3 per person per year."* (Falkenmark, 1989, p. 14).

Figure 8.3 Transboundary aquifers in Asia



No.	Name of transboundary aquifer system	Countries sharing this aquifer system	Type of aquifer system	Area (km^2)
1	Ertix River Plan	Kazakhstan, Russian Federation	1	120 000
2	West Altai	Kazakhstan, Russian Federation	1, 2	40 000
3	Ili River plain	China, Kazakhstan	1	53 000
4	Yenisei upstream	Mongolia, Russian Federation	1, 2	60 000
5	Heilongjiang River plain	China, Russian Federation	1	100 000
6	Central Asia	Afghanistan, Kazakhstan, Kyrgyzstan, Uzbekistan, Tajikistan, Turkmenistan	1, 2	660 000
7	Indus River plain	India, Pakistan	1	560 000
8	South of outer Himalayas aquifer	India, Nepal	1	65 000
9	Ganges River plain	Bangladesh, India	1	300 000
10	Salween River aquifer	Myanmar, Thailand	2	53 000
11	Mekong River plain	Cambodia, Lao People's Democratic Republic, Thailand, Viet Nam	1	220 000
12	New Guinea Island	Indonesia, Papua New Guinea	2	870 000
Type of aquifer system		1: Porous; 2: Fissured/Fractured; 3: Karst		

Source: Adapted from UNESCO Office in Beijing (2006, fig. 15, p. 18, and table 2, p. 17).

8.5.2 Transboundary cooperation

North-Western Sahara Aquifer System

The North-Western Sahara Aquifer System (NWSAS) is shared between Algeria, Libya and Tunisia, with cooperation oversight handled by the Sahara and Sahel Observatory (OSS). It is characterized by recharge levels so limited that it is considered a non-renewable water resource. It is also the sole source of water for 5 million people.

Cooperation on water at all levels, including transboundary and cross-sectoral, is of crucial importance to the Arab region

Between 1998 and 2002, the three countries in the aquifer system collaborated on the development of a common database and a mathematical model of the aquifer to improve water management. In a spirt of continued cooperation, Algeria, Libya and Tunisia in 2008 established a consultation mechanism for the NWSAS, which is intended to produce indicators on water resources availability and demand, to run various management scenarios, to maintain an updated common database, to share information, and to develop and manage monitoring systems. The consultation mechanism is headed by a council of Ministers in charge of water resources from each riparian country, and consists of a technical committee formed of national water institutions. It is important to note that while the consultation mechanism promotes cooperation, it does not impose legal restrictions on any of the riparian countries in terms of groundwater abstraction. Nevertheless, the NWSAS cooperation mechanism, which was initiated with support and funding from the international community, serves as a prototype for future cooperation mechanisms in other aquifers within the Arab region.

The NWSAS represents a rare case of well-functioning aquifer cooperation and its members have been among the most successful regionally at fulfilling SDG Indicator 6.5.2 (UNESCWA, 2015; 2019). This indicator tracks the percentage of transboundary basin area within a country that is covered by operational arrangements for water cooperation (Table 8.1).

Table 8.1: SDG Indicator 6.5.2 values in the Arab region

SDG Indicator 6.5.2 values (%)	Countries
0–10	Morocco, Qatar, Somalia, United Arab Emirates
10–30	Iraq, Jordan
30–50	
50–70	Algeria
70–90	Tunisia
90–100	Libya
Additional information is needed	Egypt, Kuwait, Lebanon, Oman, State of Palestine, Saudi Arabia
No response received	Bahrain, Djibouti, Mauritania, Sudan, Syrian Arab Republic, Yemen
Indicator not applicable	Comoros

Note: Based on the 2020 progress reports on SDG Indicator 6.5.2

Source: Based on UNESCWA (2022b).

Saq-Ram/Disi Agreement

Saq-Ram/Disi, similar to NWSAS, is a non-renewable aquifer that is shared between Jordan and Saudi Arabia. Water is pumped and transferred via a conveyance system from Disi to Amman, 350 km to the north, to supply drinking water to the city's inhabitants. The Saq-Ram/Disi Agreement between Jordan and Saudi Arabia provides another example of cooperation for the peaceful and sustainable management of scarce water resources in the region. Both countries have signed a memorandum of understanding at the technical level in 2007. This was considered as the first step towards building cooperative dialogue between two riparian countries and provides an example for other Arab countries that are engaging in bilateral discussions over transboundary water resources.

In 2015, Jordan and Saudi Arabia signed an agreement for the management and utilization of the groundwaters in the Saq-Ram/Disi aquifer. As part of the agreement, protected areas were clearly defined where no groundwater investment projects may be implemented. It was also agreed that groundwater would be used for domestic purposes only. The establishment of a joint monitoring network across both sides of the border helped to verify and assess the water level drawdown across the border and to foster information exchange. The agreement highlights the role that the water sector plays in ensuring socio-economic stability for populations in the Arab region (UNESCWA, 2022b).

8.5.3 National cooperation

There are also examples of successful cooperation around water security issues at the national level in the Arab region

Women's water user association in the Malaka Dam

There are also examples of successful cooperation around water security issues at the national level in the Arab region. In Yemen, the water of the Malaka Dam was primarily used by three neighbouring villages for irrigation and livestock, and was a subject of conflict for decades. In an attempt to halt the conflict, a tribal decree was put in place forbidding all use of the dam water. After that, a water user association (WUA) managed by women in the community, Al Malaka, took the lead in dispute resolution and peace negotiation surrounding the dam water usage. WUA members, with support from the Food and Agriculture Organization of the United Nations (FAO), were able to negotiate the implementation of a piping system that would use gravity flow to send the Malaka Dam water to several groundwater wells in the area. This solution was innovative and effective in that it eliminated the need for direct use of the dam water, while it decreased evaporation and rejuvenated well water resources. The water has since been used peacefully for livestock and irrigation in the surrounding areas. This example highlights the need for community involvement and the inclusion of women in matters of water diplomacy in the Arab region.

The FAO has continued to build on the success of the Malaka Dam story by implementing the project "Water for Peace in Yemen: Strengthening the role of women in water conflict resolution". Funded by the United Nations Secretary-General's Peacebuilding Fund, this project was implemented by the FAO, the International Organization for Migration (IOM), the Hadramout Ministry of Water and Environment, and the Women Water Users Group (WWUG). While ongoing tensions necessitated a change in the original target area of the project from the Hudaydah governorate to the Wadi Hadramout in the Hadramout governorate, the project has since shown several markers of success. Similar to the Malaka Dam project, women were involved as peace mediators to resolve disputes surrounding water use. One of the most significant outcomes of the project was that it allowed families to return to farming lands that had previously been abandoned due to a lack of irrigation. Female farmers also reported significant changes in water availability and conflict prevention between neighbouring communities (FAO, 2022).

Building climate resilience in Sudan

Climate change, population growth and environmental degradation have contributed to growing water scarcity in parts of Sudan. This has ignited incidents of isolated conflict between farmers and pastoralists as traditional migration routes are altered where once-reliable water sources are no longer present. Pastoralists are passing through new areas while farmers are also planting on migratory routes where they have not done so in the past, which generates disputes. To address this issue, in 2018 the European Union (EU) and the United Nations Environment Programme (UNEP) established a pilot project in the Wadi El Ku catchment area in North Darfur. The project established Natural Resource Management and

Peacebuilding Committees (NRMPBC). The NRMPBC's were inclusive, providing training in peacebuilding and conflict resolution to women and men from the farming and pastoralist communities. Community members worked together to identify hotspots along migratory routes and developed a joint plan for action for conflict prevention, which involved expanding migratory routes and improving access to water through the construction of a water station. Pastoralists and farmers cooperated in determining the location of the water station, while the NRMPBC was responsible for managing the use of, and access to, the water source. More than 70% of the female, and 80% of the male community members reported a decrease in the number of violent disputes over natural resources since the start of the project (UNEP/ European Union, n.d.).

8.5.4 Conclusions

The many challenges that the Arab region faces with respect to water security mean that cooperation should continue to play a key role in breaking through climate and conflict crises to ensure safe and secure access to water and sanitation for all. There are ripe opportunities available to continue to build and expand upon the current examples of cooperation around the water sector at both the transboundary and national levels.

References

ADB (Asian Development Bank). 2016. *Asian Water Development Outlook 2016: Strengthening Water Security in Asia and the Pacific*. Mandaluyong City, Philippines, ADB. www.adb.org/sites/default/files/publication/189411/awdo-2016.pdf.

AMCOW (African Ministers' Council on Water). 2012. *Status Report on the Application of Integrated Approaches to Water Resources Management in Africa*. AMCOW. www.ircwash.org/sites/default/files/AMCOW-2012-Status.pdf.

AQUASTAT. n.d. AQUASTAT FAO's Global Information System on Water and Agriculture. Rome, Food and Agriculture Organization of the United Nations (FAO). www.fao.org/aquastat/en/. (Accessed on 20 November 2023).

BCIE/Plan Trifinio (Banco Centroamericano de Integración Económica/ Plan Trifinio). 2022. *Plan Maestro para la Región Trifinio. Libro Resumen* [Master Plan for the Trifinio Region. Summary]. BCIE/Plan Trifinio. www.plantrifinio.int/nuestra-institucion/biblioteca/category/56-plan-maestro-participativo. (In Spanish.)

Boretti, A. and Rosa, L. 2019. Reassessing the projections of the World Water Development Report. *NPJ Clean Water*, Vol. 2, No. 15. doi.org/10.1038/s41545-019-0039-9.

BGR/UNESCO (Bundesanstalt für Geowissenschaften und Rohstoffe/United Nations Educational, Scientific and Cultural Organization). 2008. WHYMAP. Groundwater Resources of the World. Simplified version. Hanover, Germany/Paris, BGR/UNESCO. www.whymap.org/whymap/EN/Maps_Data/Gwr/gwr_node_en.html;jsessionid=21DD8C6D38A128D8E4E3E173D07EAC4B.internet991.

Dos Santos, M. R. W. 2023. Water cooperation within West Africa's major transboundary river basins. *Regions and Cohesion*, Vol. 13, No. 2, pp. 25–52. doi.org/10.3167/reco.2023.130203.

Dos Santos, S., Adams, E. A., Neville, G., Wada, Y., De Sherbinin, A., Mullin Bernhardt, E. M. and Adamo, S. B. 2017. Urban growth and water access in sub-Saharan Africa: Progress, challenges, and emerging research directions. *Science of the Total Environment*, Vol. 607, pp. 497–508. doi.org/10.1016/j.scitotenv.2017.06.157.

ESCAP (United Nations Economic and Social Commission for Asia and the Pacific). 2021. *SDG 6 and COVID-19: Accelerating Progress Towards SDG 6 in the Asia-Pacific Region in the Context of COVID-19 Recovery*. Policy Brief. ESCAP. www.unescap.org/kp/2021/sdg-6-covid-19-accelerating-progress-towards-sdg-6-asia-pacific-region-context-covid-19.

_____. 2022. *Mid-Term Review of the UN-Water Action Decade: Input from the Asia Pacific Roundtable Consultation*. Report Summary. ESCAP. www.unescap.org/sites/default/d8files/event-documents/UNWaterActionDecade%20AP%20consultation_0.pdf.

_____. 2023a. *Asia and the Pacific SDG Progress Report 2023: Championing Sustainability Despite Adversities*. New York, United Nations. https://repository.unescap.org/bitstream/handle/20.500.12870/5279/ESCAP-2023-FS-SDG-Progress-Report.pdf.

_____. 2023b. *Report on the Tenth Asia-Pacific Forum on Sustainable Development*. Bangkok and online, 27–30 March 2023. www.unescap.org/sites/default/d8files/event-documents/APFSD23%20report_English.pdf.

Falkenmark, M. 1989. The massive water scarcity now threatening Africa: Why isn't it being addressed? *AMBIO: A Journal of the Human Environment*, Vol. 18, No. 2, pp. 112-118.

FAO (Food and Agriculture Organization of the United Nations). 2020. *The State of Food and Agriculture 2020: Overcoming Water Challenges in Agriculture*. Rome, FAO. doi.org/10.4060/cb1447en.

_____. 2021. *Sub-Saharan Africa: Strengthening Resilience to Safeguard Agricultural Livelihoods*. Rome, FAO. doi.org/10.4060/cb8098en.

_____. 2022. *Evaluation of the Project "Water for Peace in Yemen: Strengthening the Role of Women in Water Conflict Resolution"*. Project Evaluation Series, 06/2022. Rome, FAO. www.fao.org/3/cc0674en/cc0674en.pdf.

FAO/AWP (Food and Agriculture Organization of the United Nations/ Australian Water Partnership). 2023. *Managing Water Scarcity in Asia and the Pacific – A Summary: Trends, Experiences, and Recommendations for a Resilient Future*. Rome/Canberra, FAO/AWP. doi.org/10.4060/cc6083en.

FDFA (Federal Department of Foreign Affairs, Switzerland). n.d. Switzerland and Honduras. FDFA website. www.eda.admin.ch/countries/honduras/en/home/switzerland-and.html. (Accessed on 10 April 2023).

Forbes Kazakhstan. 2022. Совместное использование водных ресурсов в Центральной Азии обсудили на региональном семинаре [Sharing Water Resources in Central Asia was discussed at a Regional Workshop]. Forbes Kazakhstan website, 3 November 2022. forbes.kz/news/2022/11/03/newsid_287963. (In Russian.)

Fraser, C. M., Kukurić, N., Dmitrieva, T. and Dumont, A. 2023. Transboundary water cooperation under SDG indicator 6.5.2: Disaggregating data to provide additional insights at the aquifer level. *Water Policy*, Vol. 25, No. 11, pp. 1015–1034. doi.org/10.2166/wp.2023.026.

Frey, F. W. 1993. The political context of conflict and cooperation over international river basins. *Water International*, Vol. 18, No. 1, pp. 438–458. doi.org/10.1080/02508069308686151.

GAFSP (Global Agriculture and Food Security Program)/INVEST-Honduras. 2021. *Alianza para el Corredor Seco. Manual de Operaciones* [Alliance for the Dry Corridor: Operation Manual]. Tegucigalpa, GAFSP. www.gdr.hn/wp-content/uploads/2021/09/MOP_ACS-PROSASUR_VersionREv-JULIO-2021-Limpio.pdf. (In Spanish.)

Galeazzi, G., Medinilla, A., Ebiede, T. M. and Desmidt, S. 2017. *Understanding the Lake Chad Basin Commission (LCBC): Water and Security at Inter-Regional Crossroads*. European Centre for Development Policy Management (ECDPM). https://ecdpm.org/application/files/1516/6134/0837/LCBC-Background-Paper-PEDRO-Political-Economy-Dynamics-Regional-Organisations-Africa-ECDPM-2017.pdf.

GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit). n.d. Tropical Forest Protection and Watershed Management in the Trifinio Region. www.giz.de/en/worldwide/13474.html.

Global Communities. 2021. *Resumen de Aprendizaje Emergente. Fortalecimiento de la Gobernanza Local para la Gestión de Cuencas Hidrográficas para el Suministro de Agua y el Riego en el Corredor Seco de Honduras* [Summary for Capacity-Building: Strenghtening Local Governance in Watershed Management for Water Supply and Irrigation in the Dry Corridor of Honduras]. Global Communities. https://mwawater.org/wp-content/uploads/2021/03/Honduras-Watershed-Management-_Emerging-Learning-Brief_6-24-2020_Spanish-Version_Final-formatted.pdf. (In Spanish.)

Government of Honduras. 2015. Más de 50 mil familias salen de la extrema pobreza con La Alianza para el Corredor Seco [Over 50 Thousand Families get out of Extreme Poverty thanks to the Alliance for the Dry Corridor]. Press release, 24 February 2015. OCHA Services Reliefweb. https://reliefweb.int/report/honduras/m-s-de-50-mil-familias-salen-de-la-extrema-pobreza-con-la-alianza-para-el-corredor. (In Spanish.)

Green, O. O., Cosens, B. A. and Garmestani, A. S. 2013. Resilience in transboundary water governance: The Okavango River Basin. *Ecology and Society*, Vol. 18, No. 2, Article 23. doi.org/10.5751/ES-05453-180223.

GWP (Global Water Partnership). 2016. *Integrated Water Resources Management in Central America: The Over-Riding Challenge of Managing Transboundary Waters*. Technical Focus Paper. Stockholm, GWP. www.gwp.org/globalassets/global/toolbox/publications/technical-focus-papers/tfp_central_america.pdf.

GWP Central America. 2021. *Estrategia de Gestión Hídrica para la Región 13 Golfo de Fonseca* [Water Management Strategy for Region 13: The Gulf of Fonseca]. GWP Central America. www.gwp.org/globalassets/global/gwp-cam_files/informe-estrategia-de-gestion-hidrica-web.pdf. (In Spanish.)

GWP-Med (Global Water Partnership-Mediterranean). 2022. *Phase II: Nexus Assessment for the Drina River Basin*. www.gwp.org/globalassets/global/gwp-med-files/list-of-programmes/see-nexus/final-reports/drina-nexus-assessment-report_final.pdf.

_____. n.d. A Nexus Roadmap for the Drina River Basin: Towards Sustainable Management of Natural Resources in the Drina River Basin through Enhanced Cooperation Across Sectors. www.gwp.org/globalassets/global/gwp-med-files/list-of-programmes/see-nexus/final-reports/drina-roadmap-final.pdf.

Hofste, R. W., Kuzma, S., Walker, S., Sutanudjaja, E. H., Bierkens, M. F. P., Kuijper, M. J. M., Faneca Sánchez, M., Van Beek, R., Wada, Y., Galvis Rodríguez, S. and Reig, P. 2019. *Aqueduct 3.0: Updated Decision- Relevant Global Water Risk Indicators. Technical Note*. Washington, World Resources Institute (WRI). www.wri.org/publication/aqueduct-30.

IEA (International Energy Agency). 2021. *Climate Impacts on Latin American Hydropower*. Paris, IEA. www.iea.org/reports/climate-impacts-on-latin-american-hydropower. Licence: CC BY 4.0.

_____. 2022. *Africa Energy Outlook 2022. World Energy Outlook Special Report*. Paris, IEA. www.iea.org/reports/africa-energy-outlook-2022. Licence: CC BY 4.0.

ILO (International Labour Organization). 2022a. *Asia–Pacific Employment and Social Outlook 2022: Rethinking Sectoral Strategies for a Human-Centred Future of Work*. Geneva, ILO. https://www.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/---publ/documents/publication/wcms_862410.pdf.

_____. 2022b. *Asia–Pacific Sectoral Labour Market Profile: Agriculture*. ILO Brief. Bangkok, ILO Regional Office for Asia and the Pacific. www.ilo.org/wcmsp5/groups/public/---asia/---ro-bangkok/documents/briefingnote/wcms_863302.pdf.

INVEST-Honduras. 2020. Plan de Participación de las Partes Interesadas y Marco de Participación de las Partes Interesadas: Proyecto "Seguridad Hídrica en el Corredor Seco de Honduras" [Stakeholder Participation Plan and Framework: Project "Water Security in the Dry Corridor of Honduras]. Tegucigalpa, INVEST-Honduras. https://documents1.worldbank.org/curated/en/610451580861623731/pdf/Stakeholder-Engagement-Plan-SEP-Water-Security-in-the-Dry-Corridor-of-Honduras-P169901.pdf. (In Spanish.)

IPCC (Intergovernmental Panel on Climate Change). 2022. *Climate Change 2022: Impacts, Adaptation, and Vulnerability*. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D. C. Roberts, M. Tignor, E. S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge, UK/New York, Cambridge University Press. doi.org/10.1017/9781009325844.

IWAC (International Water Assessment Centre). 2021. Распределение водных ресурсов в трансграничном контексте для укрепления водного сотрудничества между странами Евразии [The Allocation of Water Resources in a Transboundary Context to Strengthen Water Cooperation Between Eurasian Countries]. Nur-Sultan, Kazakhstan. (In Russian.)

Lautze, J. and Giordano, M., 2005. Transboundary water law in Africa: Development, nature, and geography. *Natural Resources Journal*, Vol. 45, Article 1053. https://digitalrepository.unm.edu/nrj/vol45/iss4/8.

Leckie, H., Smythe, H. and Leflaive, X. 2021. *Financing Water Security for Sustainable Growth in Asia and the Pacific*. OECD Environment Working Papers No. 171. Paris, OECD Publishing. doi.org/10.1787/3bc15c5b-en.

Lee, E., Jayakumar, R., Shrestha, S. and Han, Z. 2018. Assessment of transboundary aquifer resources in Asia: Status and progress towards sustainable groundwater management. *Journal of Hydrology: Regional Studies*, Vol. 20, pp. 103–115. doi.org/10.1016/j.ejrh.2018.01.004.

MacAlister, C., Baggio, G., Perera, D., Qadir, M., Taing, L. and Smakhtin, V. 2023. *Global Water Security 2023 Assessment*. Hamilton, Ont., United Nations University Institute for Water, Environment and Health (UNU-INWEH).

MacDonald, A. M., Bonsor, H. C., Dochartaigh, B. É. Ó. and Taylor, R. G. 2012. Quantitative maps of groundwater resources in Africa. *Environmental Research Letters*, Vol. 7, No. 2, Article 024009. doi.org/10.1088/1748-9326/7/2/024009.

Medinilla, A. 2017. *Understanding the International Congo–Ubangui–Sangha Commission (CICOS): Going with the Flow: From Navigation to Climate Finance in less than 20 Years*. PEDRO Background Papers.

Mirumachi, N., 2007. The politics of water transfer between South Africa and Lesotho: Bilateral cooperation in the Lesotho Highlands water project. *Water international*, Vol. 32, No. 4, pp. 558–570. doi.org/10.1080/02508060.2007.9709688.

MRC (Mekong River Commission). n.d. Mekong River Commission website. www.mrcmekong.org/ (Accessed on 21 December 2023).

Nijsten, G.-J., Christelis, G., Villholth, K. G., Braune, E. and Gaye, C. B. 2018. Transboundary aquifers of Africa: Review of the current state of knowledge and progress towards sustainable development and management. *Journal of Hydrology: Regional Studies*, Vol. 20, pp. 21–34. doi.org/10.1016/j.ejrh.2018.03.004.

OECD (Organisation for Economic Co-operation and Development). 2017. *Water Risk Hotspots for Agriculture*. OECD Studies on Water. Paris, OECD Publishing. doi.org/10.1787/9789264279551-en.

_____. 2021. *Water Governance in Asia-Pacific*. OECD Regional Development Paper No. 13. Paris, OECD Publishing. doi.org/10.1787/b57c5673-en.

Oluwasanya, G., Perera, D., Qadir, M. and Smakhtin, V. 2022. *Water Security in Africa: A Preliminary Assessment*, Issue 13. Hamilton, Ont., United Nations University Institute for Water, Environment and Health (UNU-INWEH). https://inweh.unu.edu/wp-content/uploads/2022/07/State-of-Water-Security-in-Africa-A-Preliminary-Assessment_Final_07_2022.pdf.

Prabhakar, S. V. R. K., Shivakoti, B. R., Scheyvens, H. and Corral, A. F. 2018. *Transboundary Impacts of Climate Change in Asia: Making a Case for Regional Adaptation Planning and Cooperation*. IGES Discussion Paper. Hayama, Japan, Institute for Global Environmental Strategies/Global Development Network (IGES/GDN). https://isap.iges.or.jp/2018/pdf/P4_Discussion_Paper.pdf.

SADC (Southern Africa Development Community). 1995. Protocol on Shared Watercourse Systems in the Southern African Development Community (SADC) Region. Gaborone, SADC. www.fao.org/faolex/results/details/en/c/LEX-FAOC035640.

Sadoff, C. W. and Grey, D. 2002. Beyond the river: The benefits of cooperation on international rivers. *Water Policy*, Vol. 4, No. 5, pp. 389–403. doi.org/10.1016/S1366-7017(02)00035-1.

Salazar, F. 2011. *Movimientos Sociales en torno al Agua en Bolivia: Privatización e Insurrección Social en la Guerra del Agua en Cochabamba* [Social Movements around Water in Bolivia: Privatization and Social Uprising in the Water War of Cochabamba]. Cochabamba, Bolivia, UMSS-ASDI. (In Spanish.)

Saruchera, D. and Lautze, J. 2016. Transboundary river basin organizations in Africa: Assessing the secretariat. *Water Policy*, Vol. 18, No. 5, pp. 1053–1069. doi.org/10.2166/wp.2016.228.

Savenije, H. H. G. and Van der Zaag, P. 2000. Conceptual framework for the management of shared river basins; with special reference to the SADC and EU. *Water Policy*, Vol. 2, No. 1, pp. 9–45. doi.org/10.1016/S1366-7017(99)00021-5.

Schmidt, C., Krauth, T. and Wagner, S. 2017. Export of plastic debris by rivers into the sea. *Environmental Science & Technology*, Vol. 51, No. 21, pp. 12246–12253. doi.org/10.1021/acs.est.7b02368.

SDC (Swiss Agency for Development and Cooperation). 2021. *Territorial Water Governance in the Gulf of Fonseca Region*. SDC. www.eda.admin.ch/countries/honduras/en/home/international-cooperation/projects.html/content/dezaprojects/SDC/en/2015/7F09393/phase1.

SICA (Sistema de la Integración Centroamericana). 2014. ES 3.30 Documento de Proyecto [ES 3.30 Project Document]. www.sica.int/documentos/es-3-30-documento-de-proyecto_1_89521.html. (In Spanish.)

The Economist Intelligence Unit. 2019. *The Blue Peace Index 2019: Methodology Note. A report by The Economist Intelligence Unit*. impact.economist.com/projects/bluepeaceindex/pdf/Blue%20Peace%20Index%202019_methodology%20note.pdf.

TWAP (Transboundary Waters Assessment Programme). n.d. Transboundary Waters Assessment Programme: River Basins Component. TWAP website. http://twap-rivers.org/ (Accessed on 21 November 2023).

UNECA (United Nations Economic Commission for Africa). 2021. *Progress on Transboundary Water Cooperation in Africa: Accelerating Progress on Transboundary Water Co-Operation to Achieve SDG Indicator 6.5.2*. Addis Ababa, UNECA. https://repository.uneca.org/bitstream/handle/10855/49396/b12023632.pdf?sequence=1&isAllowed=y.

UNECA/AU/AfDB (United Nations Economic Commission for Africa/African Union/African Development Bank). 2003. *Africa Water Vision for 2025: Equitable and Sustainable Use of Water for Socioeconomic Development*. Addis Ababa, UNECA. https://hdl.handle.net/10855/5488.

UNECE (United Nations Economic Commission for Europe). 2008. *What UNECE does for You …UNECE works for Better Water Management in Central Asia*. Geneva, United Nations. unece.org/DAM/highlights/what_ECE_does/English/0823837_UNECE_Water%20Management.pdf.

_____. 2021. *Handbook on Water Allocation in a Transboundary Context*. Geneva, United Nations. unece.org/sites/default/files/2022-12/ECE_MP.WAT_64_Handbook%20on%20water%20allocation%20in%20a%20the%20transboundary%20context.pdf.

UNECE/UNESCO (United Nations Economic Commission for Europe/United Nations Educational, Scientific and Cultural Organization). 2018. *Progress on Transboundary Water Cooperation: Global Baseline for SDG indicator 6.5.2*. Paris/Geneva, UNESCO/United Nations. www.unwater.org/publications/progress-transboundary-water-cooperation-global-baseline-sdg-indicator-652.

_____. 2021. *Progress on Transboundary Water Cooperation: Global Status of SDG Indicator 6.5.2 and Acceleration Needs*. New York/Paris, United Nations/UNESCO. www.unwater.org/app/uploads/2021/09/SDG6_Indicator_Report_652_Progress-on-Tranboundary-Water-Cooperation_2021_EN_UNESCO.pdf.

UNECLAC (United Nations Economic Commission for Latin America and the Caribbean). 2023. *2023 Regional Water Dialogues for Latin America and the Caribbean: Towards the United Nations Water Conference*. Santiago, UNECLAC. www.cepal.org/sites/default/files/events/files/informe_dialogos_english_2may23_ns_0.pdf.

UNEP/European Union (United Nations Environment Programme/European Union). n.d. *Building Resilience to Climate-Related Security Risks in North Darfur, Sudan*. EU-UNEP Climate Change and Security Project. wedocs.unep.org/bitstream/handle/20.500.11822/40328/climate_Sudan.pdf?sequence=3.

UNEP/OSU/FAO (United Nations Environment Programme/Oregon State University/Food and Agriculture Organization of the United Nations). 2002. *Atlas of International Freshwater Agreements*. Nairobi, UNEP. https://transboundarywaters.science.oregonstate.edu/content/atlas-international-freshwater-agreements.

UNESCO Office in Beijing (United Nations Educational, Scientific and Cultural Organization). 2006. *Transboundary Aquifers in Asia with Special Emphasis to China*. Beijing, UNESCO. https://unesdoc.unesco.org/ark:/48223/pf0000148390.

UNESCWA (United Nations Economic and Social Commission for Western Asia). 2015. *The Water, Energy and Food Security Nexus in the Arab Region. ESCWA Water Development Report 6*. E/ESCWA/SDPD/2015/2. Beirut, UNESCWA. www.unescwa.org/publications/escwa-water-development-report-6-water-energy-and-food-security-nexus-arab-region.

_____. 2019. *Moving towards Water Security in the Arab Region*. E/ESCWA/SDPD/2019/2. Beirut, UNESCWA. www.unescwa.org/publications/moving-towards-water-security-arab-region.

_____. 2022a. *Groundwater in the Arab Region*. ESCWA Water Development Report 9. E/ESCWA/CL1.CCS/2021/2. Beirut, UNESCWA. www.unescwa.org/sites/default/files/pubs/pdf/water-development-report-9-english.pdf.

_____. 2022b. *Transboundary Cooperation in Arab States: Second Regional Report on SDG Indicator 6.5.2*. E/ESCWA/CL1.CCS/2021/TP.10. Beirut, UNESCWA. www.unescwa.org/publications/sdg-indicator-6-5-2-transboundary-cooperation-arab-states.

_____. 2023. *Arab Risk Monitor: A Conceptual Framework*. www.unescwa.org/publications/arab-risk-monitor-conceptual-framework.

UNICEF (United Nations Children's Fund). 2022. Water, Sanitation & Hygiene (WASH) data. UNICEF website. https://data.unicef.org/resources/dataset/drinking-water-sanitation-hygiene-database/. (Accessed on 30 August 2023).

United Nations. 2022. *The United Nations World Water Development Report 2022: Groundwater: Making the Invisible Visible*. Paris, UNESCO. https://unesdoc.unesco.org/ark:/48223/pf0000380721.

_____. 2023a. *The United Nations World Water Development Report 2023: Partnerships and Cooperation for Water*. Paris, UNESCO. https://unesdoc.unesco.org/ark:/48223/pf0000384655.

_____. 2023b. *United Nations 2023 Water Conference Mid-Term Review of the Water Action Decade: Key Messages from the United Nations Regional Commissions*. Bangkok, United Nations. https://repository.unescap.org/rest/bitstreams/325caadb-ef00-4838-99c0-f58c572d109b/retrieve.

UN-Water. 2021. *Summary Progress Update 2021: SDG 6 – Water and Sanitation for All*. July 2021. Geneva, United Nations. www.unwater.org/publications/summary-progress-update-2021-sdg-6-water-and-sanitation-all.

_____. n.d. Sub-Saharan Africa. UN-Water website. https://sdg6data.org/en/region/Sub-Saharan%20Africa. (Accessed on 21 November 2023).

Van Koppen, B. 2003. Water reform in Sub-Saharan Africa: What is the difference? *Physics and Chemistry of the Earth*, Parts A/B/C, Vol. 28, Nos. 20–27, pp. 1047–1053. doi.org/10.1016/j.pce.2003.08.022.

Wiberg, D., Satoh, Y., Burek, P., Fischer, G., Tramberend, S., Kahil, T., Flörke, M., Eisner, S., Hanasaki, N., Wada, Y., Byers, E., Magnusziewski, P., Nava, L. F., Cosgrove, W., Lagan, S. and Scherzer, A. 2017. *Water Futures and Solutions: Asia 2050. (Final Report): Knowledge and Innovation Support for the Water Financing Program of the Asian Development Bank (RETA 6498)*. Laxenburg, Austria, International Institute for Applied Systems Analysis (IIASA). https://pure.iiasa.ac.at/14476.

Willaarts, B. A., Blanco, E., Llavona, A. and Martínez, D. 2021. *Análisis Comparativo de Acciones con Enfoque del Nexo Agua-Energía-Alimentación: Lecciones Aprendidas para los Países de América Latina y el Caribe*. Serie Recursos Naturales y Desarrollo, No. 204 (LC/TS.2021/18) [Comparative Analysis of Actions Focusing on the Water–Energy–Food Nexus: Lessons Learned for the Countries of Latin America and the Caribbean. Natural Resources and Development Series, No. 204 (LC/TS.2021/18)]. Santiago, United Nations Economic Commission for Latin America and the Caribbean (UNECLAC). https://hdl.handle.net/11362/46713. (in Spanish.)

Wilson, M., Nanau, G., Sobey, M. and Lotawa, S. 2022. *Political Economy of Water Management and Community Perceptions in the Pacific Island Countries*. Australian Aid/The Australian Water Partnership/The Asia Foundation. https://asiafoundation.org/wp-content/uploads/2022/10/Political-Economy-of-Water-Resources-Management-and-Community-Perceptions-in-the-Pacific-Island-Countries.pdf.

WMO (World Meteorological Organization). 2021. *WMO Atlas of Mortality and Economic Losses from Weather, Climate and Water Extremes (1970–2019)*. Geneva, WMO. https://library.wmo.int/doc_num.php?explnum_id=10989.

World Bank. n.d. South Asia Water Initiative (SAWI). World Bank website. www.worldbank.org/en/programs/sawi#1. (Accessed on 30 August 2023).

WWAP (UNESCO World Water Assessment Programme). 2019. *The United Nations World Water Development Report 2019: Leaving No One Behind*. Paris, UNESCO. https://unesdoc.unesco.org/ark:/48223/pf0000367306.

Chapter 9

Governance

WWAP

Dustin Garrick, Richard Connor and Leah Jones-Crank

With contributions from: Susanne Schmeier (IHE Delft)

Water governance contributes to prosperity and peace by addressing competition and resolving disputes over water. Effective and equitable water allocation encourages investment and benefit-sharing, and ultimately promotes social cohesion. The complexities of water management – the range of issues, actors, and jurisdictions – expands beyond the basin and across sectors. Leveraging water for prosperity and peace requires governance capacity and political will to address water allocation and adaptation challenges across sectors and supply chains, with key roles for a broadening group of actors in government ministries, civil society organizations, and markets (Meinzen-Dick, 2007; Woodhouse and Muller, 2017).

Intensified competition for water highlights connections between different areas (e.g. upstream/downstream) and across different sectors (Molle et al., 2010). In this context, water governance involves a challenge of multi-level collective action, and specifically a challenge of water allocation and reallocation.

9.1 Linking water governance with prosperity and peace

Water governance refers to the *"ways societies organize themselves to make decisions"*, with growing calls to move beyond *"water-centric"* approaches, taking greater account of the root of the problems to be addressed, and the decisions and actors involved (De Loë and Patterson, 2017, p. 76). Growing scarcity, access inequalities, and shocks from outside the water sector have increased interdependencies, intensifying competition for water and creating complex economic spillovers.

Safeguarding peace and promoting prosperity requires sufficient oversight and investment in water-related public services, including irrigation systems, drinking water supply, ecosystem conservation, as well as recreational and spiritual values (Ostrom, 1962; Briscoe, 2014; United Nations, 2023). Water governance must therefore also account for, and ideally influence, decisions in the agricultural, energy, health and infrastructure sectors (Gupta et al., 2013; Wang-Erlandsson et al., 2022), as well as the informal sector when it plays a significant role (e.g. water vending or solar powered groundwater irrigation) (Wutich et al., 2023).

Water governance contributes to prosperity and peace by addressing competition and resolving disputes over water

Equitable governance arrangements, designed to manage complex trade-offs, are required in order to navigate tensions and redress injustices of water supply and allocation (Sultana, 2018). This includes efforts to craft and implement rules for establishing and (re)allocating water rights across competing uses and values and mobilizing the financing required (Garrick et al., 2017).

Dating (at least) back to the Dublin Principles of 1992, calls for integrated and cross-sectoral approaches to water allocation and governance are not new. However, integration is costly and contentious, requiring human, social and financial capital beyond the reach of many of even the wealthiest regions (Bromley and Anderson, 2018). Local governance plays a particularly critical role when capacity is limited, especially where service provision is decentralized. For example, in parts of West Africa, packaged water distributed by water vendors has become the de facto option in regions lacking municipal water supplies (Wutich et al., 2023), creating a need for recognition and integration of informal and formal water providers through regional partnerships and diverse governance models that combine public and private roles across scales (Koehler et al., 2021).

As economies diversify from agriculture and resource extraction towards process manufacturing industries and services, the overall changes in water use have at times been neglected (Molle et al., 2010). Agricultural trade has allowed regions to decouple economic development from local water use, as food becomes increasingly imported, but these benefits come with the risk of 'water grabbing' in regions where food exports occur without local consent (Dell'Angelo et al., 2021) and potential for sacrifice zones of localized groundwater depletion where export-driven agricultural is unsustainable (Graham et al., 2023).

Leveraging water for peace also involves governance arrangements that both avoid and manage disputes. The most prominent mechanisms include international frameworks and norms for meeting the human rights to water and protecting water sources and systems, particularly during armed conflicts and in transboundary settings (Tignino, 2016). Treaties and associated river basin organizations coordinate development and management of shared waters (Schmeier and Shubber, 2018), with an increasing recognition that transboundary cooperation involves a multi-level collective challenge (see Chapter 7).

Joint monitoring and data-sharing serve as a basis for sound cooperation (United Nations, 2023). In the context of the Mekong River, the Great Lakes of North America, and the Danube River, science supports water diplomacy by taking stock of basin conditions, forecasting possible futures, developing new understandings and reviewing the state of knowledge on key issues of interest (Milman and Gerlak, 2020). Knowledge-sharing can also support informal governance mechanisms, including data-sharing, coordination across sectors, and creative financing mechanisms to share risks and benefits.

9.2 Water governance and allocation

In some cases, river basin development has enabled prosperity through coordinated infrastructure development. The Tennessee Valley Authority is the iconic example of this integrated vision, but one that has proven hard to replicate or adapt for other regions due to the politics and costs of integrated approaches (Molle et al., 2010; Boccaletti, 2021).

Short-sighted river basin development can increase exposure to risks, particularly when downstream needs are unmet (Molle, 2009). There is also an increasing recognition of the influence of processes that originate outside basin boundaries, such as climate hazards, geopolitical instability, or supply chain disruptions and commodity shocks (De Loë and Patterson, 2017). The changing patterns of supply and demand, coupled with the evolving goals of societies for water development, have led to growing calls for improved water allocation as a means to increase economic efficiency and contribute to growth (World Bank Group, 2016), while addressing inequalities and injustices in water financing and sharing (Rockström et al., 2023; Wheeler et al., 2023). The examples of specific cities – São Paulo, Singapore, Cape Town – running dry have illustrated that these economic impacts are not a distant threat (Box 9.1, see also Garrick et al., 2019). This has made allocation (and reallocation) a major priority in water policy and governance.

Joint monitoring and data-sharing serve as a basis for sound cooperation

Water allocation determines who gets water when, how, and under which conditions. It is therefore fundamental to address and meet established priorities, as captured in the human right to water and Sustainable Development Goal (SDG) 6. Meeting the basic needs of people is a human right and the top priority among competing uses, followed typically by water for consumptive (food, industry) and non-consumptive (hydropower, recreation) needs.

Environmental flows and ecosystem services underpin the long-term sustainability of economies and cultures. Some countries, ranging from South Africa and Australia to Ecuador, have struggled to recognize and restore environmental flows through a range of tools, ranging from constitutional reforms to payments for hydrological services (Anderson et al., 2019). In many contexts, water allocation policies were developed under a principle of aqua *nullius*. This has excluded indigenous peoples from establishing and enforcing rights, prompting efforts to redress legacies of exclusion (O'Donnell et al., 2023).

Without improvements in water allocation frameworks, economic growth rates have been projected to decline by as much as 6% by 2050 in some regions due to impacts of water shortages on health, agriculture and incomes (World Bank Group, 2016). The World Bank Group (2016) identified three priorities for water allocation reform: (i) to optimize water use through planning and incentives, including efficiency improvements within

Box 9.1 Water, energy, and food interdependencies in cities

Cities are facing newly recognized forms of interdependencies between water and related resources. Water, energy and food are key resources for societal flourishing and are strongly interrelated within a system. Taking a water–energy–food (WEF) nexus approach helps to reduce unintended consequences and increase resource security for water and related resources. Singapore and Cape Town provide illustrative examples of such interdependencies. In Singapore, the water sector is heavily energy-dependent, as NEWater (water reuse) and desalination are large components of the nation's water portfolio (Lenouvel et al., 2014). In Cape Town, resource interdependence became evident during the 2018 water crisis, as water allocation was shared between the city and the surrounding agricultural areas. This led to finger-pointing regarding who was to blame for the crisis, instead of proactive coordination across resource sectors and governance scales (Enqvist and Ziervogel, 2019; Jones et al., 2022).

Cities are responding to these interdependencies in various ways. Historically, when Singapore gained independence in 1965, it relied heavily on its neighbour Malaysia for water resources. Given the political tension between the two countries, Singapore made water independence a priority. However, Singapore has limited natural water resources (no natural lakes, no groundwater, and limited streams), requiring innovative approaches to secure its water supply, which in turn required steady, affordable and accessible energy sources (Tortajada and Wong, 2018). Secure energy resources, along with extensive investment in research and development, paved the way for large-scale water reuse and desalination, allowing Singapore to increase its water independence and improve national peace and security by reducing the impact that political tensions with Malaysia could have on its water resources. Looking to the future, Cape Town has developed a Water Strategy, formulating the city-wide priority to achieve water resilience and to become a water-sensitive city. This new strategy involves the direct inclusion of agricultural stakeholders and the consideration of agricultural water use for future water planning (City of Cape Town, 2019).

Singapore and Cape Town provide development pathways for water resources that contribute towards increased adaptive capacity within the water sector and across various sectors for peace and prosperity.

sectors and allocation across sectors to improve productivity, flexibility and shifts between uses as values change; (ii) when appropriate, to expand supplies, including groundwater management and unconventional supplies, whilst ensuring services to the poor, safeguarding the environment, and providing mechanisms for conflict resolution and adjustment; and (iii) to reduce the impacts of weather-related shocks, including informational and early warning systems, and mechanisms for risk-sharing and -pooling, such as insurance.

Water allocation involves the distribution of different types of permits or property rights to water, including rights to access, withdraw and use water. Decisions about allocating water occur at multiple levels, from within the household to between sectors or across political borders. In China, for example, reforms in 2002 established a hierarchical framework for water rights with key decision-making roles at the central, local (regional/provincial) and user level (Wang et al., 2018). These property rights to water can be formal and encoded in regulations and court decrees, or informal and grounded in customary tenure arrangements (Rights and Resources Initiative and Environmental Law Institute, 2020). In the case of the latter, water grabbing by external actors (outside of the community) threatens local control and has led to increasing resistance to defend rights and rural livelihoods (Dell'Angelo et al., 2021).

There are three main approaches to allocating water: community-level decisions, administrative or court decrees, and market mechanisms and economic instruments. These are nearly always blended in practice and across scales (Meinzen-Dick, 2007; Meinzen-Dick and Ringler, 2008; Bruns and Meinzen-Dick, 2022). For example, irrigation systems governed by water user associations (WUAs) (Villamayor-Tomas et al., 2022), have long relied on community-level decisions, but competition across irrigation districts or across sectors increases reliance on administrative and court decisions (e.g. Garrick et al., 2019). In practice, WUAs, governments and markets rarely operate independently, so the priority has been to develop an 'institutional tripod' (Meinzen-Dick, 2007) that involves communities, markets and governments in a set of key tasks for information-gathering, infrastructure development, and decision-making about water extraction limits and water-sharing agreements. The need for clear roles and responsibilities, robust allocation mechanisms, and the nesting of governance capacity and coordination across levels were found as the common elements for river basins seeking to adapt to water scarcity and growing urbanization (Grafton et al., 2013; Garrick et al., 2017; Ma'Mun et al., 2020).

Groundwater development has also driven allocation reforms to address depletion and water quality issues through conditions on water rights (OECD, 2017). Local and national governments have struggled to enforce regulatory limits on pumping (Closas and Villholth, 2020), making groundwater allocation an urgent priority for sustaining and sharing prosperity (Rodella et al., 2023). Active involvement of farmer organizations, and appropriate incentives and institutions at multiple levels, have been identified as keys to success (Bruns and Meinzen-Dick, 2022).

The process of allocating or reallocating water is intensely political and faces a number of challenges (Hellegers and Laflaive, 2015). First, there is no 'ideal approach'. Models from one region can rarely be transferred directly to others, as illustrated by initial efforts to spread the Australian model for cap-and-trade to other regions facing water scarcity (Grafton, 2019).

Second, water is not always a top policy priority, which creates the need for tools and processes that place water allocation decision-making in the context of other policies, such as trade/market mechanisms or agricultural subsidies (Garrick et al., 2022, Villamayor-Tomas et al., 2015). For example, decisions by ministries responsible for trade and agriculture that bypass conventional water governance channels can directly affect resource availability and restrict water access to different user groups (Graham et al., 2023).

Third, many allocation systems struggle with change; this has driven attention to water-sharing arrangements that are 'adaptive'. Water rights that involve 'shares' (a proportion of water available) are often more equitable than approaches with winner-takes-it-all outcomes, and are more likely to promote risk- and benefit-sharing (Schlager and Heikkila, 2011).

Finally, distributional disagreements and vested interests can block change when existing water users benefit from maintaining the status quo (Heinmiller, 2009). The stalemate associated with vested interests highlights the need for safeguards and compensation mechanisms, and initiatives that link water rights reforms with broader regional and rural development policies (White, 1957). Including the affected parties in decisions about water rights reform bolsters trust in the decision-making process and legitimacy of outcomes. In São Paulo (Brazil), for example, the inter-basin agreements sharing the Cantareira system involved steadily more inclusive efforts to adjust water-sharing with input from affected rural communities (De Souza Leão and De Stefano, 2019). Broadening participation allowed for adaptation of the agreements to account for changing conditions associated with urbanization and climate variability in a way that better accounted for the needs and livelihoods in the source region.

The major challenge has been to scale up coordination across multiple scales and sectors. There are four conditions identified for supporting multi-level governance: (i) joint monitoring and information-gathering (e.g. water accounting across irrigation and urban water supply systems); (ii) availability of dispute resolution mechanisms (e.g. a spectrum from informal forums to administrative and court decisions); (iii) external recognition (by higher-level authorities) and capacity-building of local or subnational authorities (e.g. funding and grants for technical teams, participatory processes); and (iv) development of 'integration mechanisms' that range from informal networks to associations and coordination agencies (e.g. river basin organizations, river basin authorities) (Garrick et al., 2017; Marshall, 2008).

Examples of cross-sectoral coordination include regional authorities engaged in subnational agreements that address competition between rural and urban water users, such as the Metropolitan Water District of Southern California in the United States of America (USA) (Hughes and Pincetl, 2014), the above-mentioned regional-level water rights reform in China (Wang et al., 2018), or interjurisdictional agreements that have taken hold from Spain to the USA (Schlager and Heikkila, 2011). Crucial to these efforts to 'scale up' water allocation are governance arrangements that allow for key groups to identify common interests and build coalitions for generating and sharing benefits.

While purely volumetric water allocation generates a zero-sum outcome (winners and losers), benefit-sharing makes win–win opportunities possible

9.2.1 Benefit-sharing

Benefit-sharing involves shifting from allocating physical quantities of water to sharing broader outcomes (e.g. energy and food security, or disaster risk reduction). While purely volumetric water allocation generates a zero-sum outcome (winners and losers), benefit-sharing makes win–win opportunities possible (United Nations, 2023). The Columbia River basin in the Pacific Northwest region of the USA and the Lesotho Highlands of Southern Africa are two examples where hydropower production in transboundary rivers upstream generates benefits shared (and paid for in part) by downstream beneficiaries (Xie et al., 2023; Yu, 2008).

Sadoff and Grey (2002) extended the benefit-sharing paradigm to transboundary rivers in their four-pronged typology of benefits to the river, from the river, because of the river, and beyond it. Benefits to the river comprise river health and the protection or restoration of aquatic ecosystems and water quality. The river generates benefits from energy and food production, and cooperation can produce benefits by reducing the risks caused by the river (such as flooding or geopolitical tensions). The benefits beyond the river comprise economic development and the positive spillover benefits of water investments that can enable economic growth.

The promise of benefit-sharing has not been fully realized (Dombrowsky, 2009).

Win–win outcomes are likely to be harder to achieve as more objectives, stakeholders or constraints are addressed (Hegwood et al., 2022). Win–win outcomes involve hidden costs (e.g. where virtual water-trading neglects impacts on small-scale farmers and those with informal tenure arrangements for land and water). There are also practical reasons and constraints on benefits that are not easily measured and quantified (e.g. where environmental flows or restoration are part of the benefit-sharing). Finally, outcomes are not necessarily evenly distributed, for example in cases where water flows from agriculture to cities but the cities capture the largest share of the benefits (Libecap, 2009).

The proportionality principle (Ostrom, 2010) focuses on the sharing of benefits in proportion to the costs and risks incurred. Those who bear the risks and costs should reap the rewards, but this principle implies the need for safety nets provided by communities and governments to address those left behind. The counterargument highlights that such arrangements can work reasonably well in the context of small groups with relatively limited levels of inequality (Kashwan et al., 2021).

The potential for benefit-sharing hinges on investments in governance capacity and water allocation reforms, as well as supporting information about water accounting, water use and water rights. Achieving the potential for benefit-sharing requires investing in governance, not just infrastructure (Schmeier, 2015; Whittington et al., 2013).

9.3 Water development paths

Water development paths refer to a sequence of different interventions and investments, and allows for a perspective beyond individual projects, to look at longer-term trajectories and outcomes (Whittington et al., 2013; Brown et al., 2022). A focus on pathways highlights how water governance can be leveraged for peace and prosperity by providing the enabling environment for financing water and addressing wider policy objectives associated with water.

Because water supply, values and uses evolve, water development paths involve a sequence of policies, regulations and investments, as well as information, infrastructure and institutions that facilitate dispute resolution and water reallocation when patterns of supply and demand change (Gleick, 2018). This adaptive capacity requires investments in water governance capacity in a phased way in order to achieve broader development outcomes linked to peace and prosperity.

Economic development depends on water infrastructure, both grey and green, for drinking water and sanitation, agriculture, energy production, and ecosystem services. It also depends on the ability to share these benefits and ensure flexibility to adjust over time. Environmental co-benefits (e.g. biodiversity, flood & pollution control) have been shown to motivate partners to engage in more collaborative approaches to water management (United Nations, 2023) and can therefore help guide and consolidate efforts to coordinate allocation decisions at the river basin level. The International Union for Conservation of Nature (IUCN, 2020) highlights five categories of co-benefits: economic, social, ecosystem, regional development, and security benefits. The economic and regional development categories correspond to direct benefits (e.g. livelihoods, production) and indirect benefits (e.g. cross-border investment), respectively. Cooperation in Monterrey (Mexico) over the Río San Juan (a tributary to the Río Bravo/Río Grande), for example, provides direct benefits to those in the city and irrigation districts, and indirect benefits through contributions to national security, regional growth and trade (see Box 3.1 in United Nations, 2023). Water-sharing agreements in the early to mid-1990s have since shifted the perspective of downstream agricultural communities from one of 'win–lose' to 'win–win' outcomes (Aguilar-Barajas and Garrick, 2019). However, the benefit-sharing agreements exclude environmental and instream flows, which means that the 'win–win' outcome comes with hidden costs (Hegwood et al., 2022).

The recent focus on blended financing for water infrastructure – the combination of public and private investment from multiple sources in each of these categories (United Nations, 2022) – highlights the principle of risk- and benefit-sharing. As infrastructure and investment needs cut across sectors or scales, safeguards are needed, starting with meeting the human right to water and meeting basic needs backed by capacity for implementation. This speaks to the need to finance not only infrastructure but also maintenance and management.

Governing water to promote prosperity and peace requires that supply development and demand management are coordinated. River basin development paths such as the Colorado River basin illustrate how allocation agreements (e.g. the Colorado River compact) predated and enabled the public (and private) investments that came after. This points to the importance of sequencing to ensure that governance capacity is in place prior to infrastructure development and to thereafter strengthen institutions that can adapt to changing conditions. It also requires focusing on tailoring water governance to the local context. Particularly in regions with variable climates, water allocation rules that share risks proportionally can prove more equitable than rules that prioritize one user over others. In this context, efforts to improve water allocation and governance may involve a ladder of interventions and a growing coordination of allocation and financing decisions – a set of increasingly complex policy and institutional responses as pressures and capacities grow.

References

Aguilar-Barajas, I. and Garrick, D. E. 2019. Water reallocation, benefit sharing, and compensation in northeastern Mexico: A retrospective assessment of El Cuchillo Dam. *Water Security*, Vol. 8, Article 100036. doi.org/10.1016/j.wasec.2019.100036.

Anderson, E. P., Jackson, S., Tharme, R. E., Douglas, M., Flotemersch, J. E., Zwarteveen, M., Lokgariwar, C., Montoya, M., Wali, A., Tipa, G. T., Jardine, T. D., Olden, J. D., Cheng, L., Conallin, J., Cosens, B., Dickens, C., Garrick, D. E., Groenfeldt, D., Kabogo, J., Roux, D. J., Ruhi, A. and Arthington, A. H. 2019. Understanding rivers and their social relations: A critical step to advance environmental water management. *Wiley Interdisciplinary Reviews (WIREs): Water*, Vol. 6, No. 6, Article e1381. doi.org/10.1002/wat2.1381.

Boccaletti, G. 2021. *Water: A Biography*. New York, Vintage Books.

Briscoe, J. 2014. The Harvard water federalism project – process and substance. *Water Policy*, Vol. 16, No. S1, pp. 1–10. doi.org/10.2166/wp.2014.001.

Bromley, D. W. and Anderson, G. 2018. Does water governance matter? *Water Economics and Policy*, Vol. 4, No. 3, Article 1750002. doi.org/10.1142/S2382624X17500023.

Brown, C., Boltz, F. and Dominique, K. 2022. *Strategic Investment Pathways for Resilient Water Systems*. OECD Environment Working Papers No. 202. Paris, OECD Publishing. doi.org/10.1787/9afacd7f-en.

Bruns, B. R. and Meinzen-Dick, R. S. 2022. *Combining and Crafting Institutional Tools for Groundwater Governance*. IFPRI Discussion Paper No. 02158. Washington, International Food Policy Research Institute (IFPRI). doi.org/10.2499/p15738coll2.136518.

City of Cape Town. 2019. *Our Shared Water Future: Cape Town's Water Strategy*. http://resource.capetown.gov.za/documentcentre/Documents/City strategies%2C plans and frameworks/Cape Town Water Strategy.pdf.

Closas, A. and Villholth, K. G. 2020. Groundwater governance: Addressing core concepts and challenges. *Wiley Interdisciplinary Reviews (WIREs): Water,* Vol. 7, No. 1, Article e1392. doi.org/10.1002/wat2.1392.

Dell'Angelo, J., Navas, G., Witteman, M., D'Alisa, G., Scheidel, A. and Temper, L. 2021. Commons grabbing and agribusiness: Violence, resistance and social mobilization. *Ecological Economics*, Vol. 184, Article 107004. doi.org/10.1016/j.ecolecon.2021.107004.

De Loë, R. C. and Patterson, J. J. 2017. Rethinking water governance: Moving beyond water-centric perspectives in a connected and changing world. *Natural Resources Journal*, Vol. 57, No. 1, pp. 75–100.

De Souza Leão, R. and De Stefano, L. 2019. Making concrete flexible: Adapting the operating rules of the Cantareira water system (São Paulo, Brazil). *Water Security*, Vol. 7, Article 100032. doi.org/10.1016/j.wasec.2019.100032.

Dombrowsky, I. 2009. Revisiting the potential for benefit sharing in the management of trans-boundary rivers. *Water Policy*, Vol. 11, No. 2, pp. 125–140. doi.org/10.2166/wp.2009.020.

Enqvist, J. P. and Ziervogel, G. 2019. Water governance and justice in Cape Town: An overview. *Wiley Interdisciplinary Reviews (WIREs): Water*, Vol. 6, No. 4, Article e1354. doi.org/10.1002/wat2.1354.

Garrick, D. E., Hall, J. W., Dobson, A., Damania, R., Grafton, R. Q., Hope, R., Hepburn, C., Bark, R., Boltz, F., De Stefano, L. O'Donnell, E., Matthews, N. and Money, A. 2017. Valuing water for sustainable development. *Science*, Vol. 358, No. 6366, pp. 1003–1005. doi.org/10.1126/science.aao4942.

Garrick, D. E., De Stefano, L., Yu, W., Jorgensen, I., O'Donnell, E., Turley, L., Aguilar-Barajas, I., Dai, X., De Souza Leão, R., Punjabi, B., Schreiner, B., Svensson, J. and Wight, C. 2019. Rural water for thirsty cities: A systematic review of water reallocation from rural to urban regions. *Environmental Research Letters*, Vol. 14, No. 4, Article 043003. doi.org/10.1088/1748-9326/ab0db7.

Garrick, D. E., Alvarado-Revilla, F., De Loë, R.C. and Jorgensen, I. 2022. Markets and misfits in adaptive water governance: How agricultural markets shape water conflict and cooperation. *Ecology and Society*, Vol. 27, No. 4. doi.org/10.5751/ES-13337-270402.

Gleick, P. H. 2018. Transitions to freshwater sustainability. *Proceedings of the National Academy of Sciences (PNAS)*, Vol. 115, No. 36, pp. 8863–8871. doi.org/10.1073/pnas.1808893115.

Grafton, R. Q. 2019. Policy review of water reform in the Murray–Darling Basin, Australia: The "do's" and "do'nots". *The Australian Journal of Agricultural and Resource Economics*, Vol. 63, No. 1, pp. 116–141. doi.org/10.1111/1467-8489.12288.

Grafton, R. Q., Pittock, J., Davis, R., Williams, J., Fu, G., Warburton, M., Udall, B., McKenzie, R., Yu, X., Che, N., Connell, D., Jiang, Q., Kompas, T., Lynch, A., Norris, R., Possingham, H. and Quiggin, J. 2013. Global insights into water resources, climate change and governance. *Nature Climate Change*, Vol. 3, pp. 315–321. doi.org/10.1038/nclimate1746.

Graham, N. T., Iyer, G., Wild, T. B., Dolan, F., Lamontagne, J. and Calvin, K. 2023. Agricultural market integration preserves future global water resources. *One Earth*, Vol. 6, No. 9, pp.1235–1245. doi.org/10.1016/j.oneear.2023.08.003.

Gupta, J., Pahl-Wostl, C. and Zondervan, R. 2013. 'Glocal' water governance: A multi-level challenge in the anthropocene. *Current Opinion in Environmental Sustainability*, Vol. 5, No. 6, pp. 573–580. doi.org/10.1016/j.cosust.2013.09.003.

Hegwood, M., Langendorf, R. E. and Burgess, M. G. 2022. Why win–wins are rare in complex environmental management. *Nature Sustainability*, Vol. 5, pp. 674–680. doi.org/10.1038/s41893-022-00866-z.

Hellegers, P. and Leflaive, X. 2015. Water allocation reform: What makes it so difficult? *Water International*, Vol. 40, No. 2, pp. 273–285. doi.org/10.1080/02508060.2015.1008266.

Heinmiller, T. 2009. Path dependency and collective action in common pool governance. *International Journal of the Commons*, Vol. 3, No. 1, pp. 131–147. doi.org/10.18352/ijc.79.

Hughes, S. and Pincetl, S., 2014. Evaluating collaborative institutions in context: The case of regional water management in southern California. *Environment and Planning C: Government and Policy*, Vol. 32, No. 1, pp. 20–38. doi.org/10.1068/c1210.

IUCN (International Union for Conservation of Nature). 2020. *Sharing the Benefits from River Basin Management. From Theory to Practice*. Gland, Switzerland, IUCN. www.iucn.org/sites/default/files/content/documents/2021/iucn_benefit_sharing_river_basin_management_final_march2021_vs2.pdf.

Jones, J. L., White, D. D. and Thiam, D. 2022. Media framing of the Cape Town water crisis: Perspectives on the food–energy–water nexus. *Regional Environmental Change*, Vol. 22, Article 79. doi.org/10.1007/s10113-022-01932-0.

Kashwan, P., Mudaliar, P., Foster, S. R. and Clement, F. 2021. Reimagining and governing the commons in an unequal world: A critical engagement. *Current Research in Environmental Sustainability*, Vol. 3, Article 100102. doi.org/10.1016/j.crsust.2021.100102.

Koehler, J., Thomson, P., Goodall, S., Katuva, J. and Hope, R. 2021. Institutional pluralism and water user behavior in rural Africa. *World Development*, Vol. 140, Article 105231. doi.org/10.1016/j.worlddev.2020.105231.

Lenouvel, V., Lafforgue, M., Chevauché, C. y Rhétoré, P. 2014. The energy cost of water independence: The case of Singapore. *Water Science and Technology*, Vol. 70, No. 5, pp. 787–794. doi.org/10.2166/wst.2014.290.

Libecap, G.D., 2009. Chinatown revisited: Owens Valley and Los Angeles—bargaining costs and fairness perceptions of the first major water rights exchange. *Journal of Law, Economics, & Organization*, Vol. 25, No. 2, pp. 311–338. doi.org/10.1093/jleo/ewn006.

Ma'Mun, S. R., Loch, A. and Young, M. D. 2020. Robust irrigation system institutions: A global comparison. *Global Environmental Change*, Vol. 64, Article 102128. doi.org/10.1016/j.gloenvcha.2020.102128.

Marshall, G.R., 2008. Nesting, subsidiarity, and community-based environmental governance beyond the local scale. *International Journal of the Commons*, Vol. 2, No. 1, pp. 75–97.

Meinzen-Dick, R. 2007. Beyond panaceas in water institutions. *Proceedings of the National Academy of Sciences (PNAS)*, Vol. 104, No. 39, pp. 15200–15205. doi.org/10.1073/pnas.0702296104.

Meinzen-Dick, R. and Ringler, C. 2008. Water reallocation: Drivers, challenges, threats, and solutions for the poor. *Journal of Human Development*, Vol. 9, No. 1, pp. 47–64. doi.org/10.1080/14649880701811393.

Milman, A. and Gerlak, A. K. 2020. International river basin organizations, science, and hydrodiplomacy. *Environmental Science & Policy*, Vol. 107, pp. 137–149. doi.org/10.1016/j.envsci.2020.02.023.

Molle, F. 2009. River-basin planning and management: The social life of a concept. *Geoforum*, Vol. 40, No. 3, pp. 484–494. doi.org/10.1016/j.geoforum.2009.03.004.

Molle, F., Wester, P. and Hirsch, P. 2010. River basin closure: Processes, implications and responses. *Agricultural Water Management*, Vol. 97, No. 4, pp. 569–577. doi.org/10.1016/j.agwat.2009.01.004.

O'Donnell, E., Kennedy, M., Garrick, D. E., Horne, A. and Woods, R. 2023. Cultural water and indigenous water science. *Science*, Vol. 381, No. 6658, pp. 619–621. doi.org/10.1126/science.adi0658.

OECD (Organisation for Economic Cooperation and Development). 2017. *Groundwater Allocation: Managing Growing Pressures on Quantity and Quality*. OECD Studies on Water. Paris, OECD Publishing. doi.org/10.1787/9789264281554-en.

Ostrom, E. 2010. Beyond markets and states: Polycentric governance of complex economic systems. *American Economic Review*, Vol. 100, No. 3, pp. 641–672. doi.org/10.1257/aer.100.3.641.

Ostrom, V. 1962. The political economy of water development. *The American Economic Review*, Vol. 52, No. 2, pp. 450–458.

Rights and Resources Initiative and Environmental Law Institute. 2020. *Whose Water? A Comparative Analysis of National Laws and Regulations Recognizing Indigenous Peoples', Afro-descendants', and Local Communities' Water Tenure*. Washington, Rights and Resources Initiative. https://rightsandresources.org/publication/whose-water/.

Rockström, J., Mazzucato, M., Andersen, L. S., Fahrländer, S. F. and Gerten, D. 2023. Why we need a new economics of water as a common good. *Nature*, Vol. 615, No. 7954, pp. 794–797. doi.org/10.1038/d41586-023-00800-z.

Rodella, A.-S., Zaveri, E. and Bertone, F. (eds.). 2023. *The Hidden Wealth of Nations: The Economics of Groundwater in Times of Climate Change*. Washington, World Bank. http://hdl.handle.net/10986/39917. Licence: CC BY 3.0 IGO.

Sadoff, C. W. and Grey, D. 2002. Beyond the river: The benefits of cooperation on international rivers. *Water Policy*, Vol. 4, No. 5, pp. 389–403. doi.org/10.1016/S1366-7017(02)00035-1.

Schlager, E. and Heikkila, T. 2011. Left high and dry? Climate change, common-pool resource theory, and the adaptability of western water compacts. *Public Administration Review*, Vol. 71, No. 3, pp. 461–470. doi.org/10.1111/j.1540-6210.2011.02367.x.

Schmeier, S. 2015. The institutional design of river basin organizations–empirical findings from around the world. *International Journal of River Basin Management*, Vol. 13, No. 1, pp.51–72. doi.org/10.1080/15715124.2014.963862.

Schmeier, S. and Shubber, Z. 2018. Anchoring water diplomacy – The legal nature of international river basin organizations. *Journal of Hydrology*, Vol. 567, pp. 114–120. doi.org/10.1016/j.jhydrol.2018.09.054.

Sultana, F. 2018. Water justice: why it matters and how to achieve it. *Water International*, Vol. 43, No. 4, pp. 483–493. doi.org/10.1080/02508060.2018.1458272.

Tignino, M. 2016. Water during and after armed conflicts: What protection in international law? *Brill Research Perspectives in International Water Law*, Vol. 1, No. 4, pp. 1–111. doi.org/10.1163/23529369-12340004.

Tortajada, C. and Wong, C. 2018. Quest for water security in Singapore. World Water Council (eds.), *Global Water Security: Lessons Learnt and Long-Term Implications*. Springer Singapore, (pp. 85–115). doi.org/10.1007/978-981-10-7913-9_4.

United Nations. 2022. *The United Nations World Water Development Report 2022 – Groundwater: Making the Invisible Visible*. Paris, United Nations Educational, Scientific and Cultural Organization (UNESCO). https://unesdoc.unesco.org/ark:/48223/pf0000380721.

_____. 2023. *The United Nations World Water Development Report 2023: Partnerships and Cooperation for Water*. Paris, United Nations Educational, Scientific and Cultural Organization (UNESCO). https://unesdoc.unesco.org/ark:/48223/pf0000384655.

Villamayor-Tomas, S., Grundmann, P., Epstein, G., Evans, T. and Kimmich, C. 2015. The water–energy–food security nexus through the lenses of the value chain and the institutional analysis and development frameworks. *Water Alternatives*, Vol. 8, No. 1, pp. 735–755. www.water-alternatives.org/index.php/all-abs/274-a8-1-7/file.

Villamayor-Tomas, S., Hermann, A., Van der Lingen, L. and Hayes, T. 2022. Community-based water markets and collective payment for ecosystem services: Toward a theory of community-based environmental markets. *Current Opinion in Environmental Sustainability*, Vol. 59, Article 101221. doi.org/10.1016/j.cosust.2022.101221.

Wang, Y., Wan, T. and Biswas, A. K. 2018. Structuring water rights in China: A hierarchical framework. *International Journal of Water Resources Development*, Vol. 34, No. 3, pp. 418–433. doi.org/10.1080/07900627.2017.1378627.

Wang-Erlandsson, L., Tobian, A., Van der Ent, R. J., Fetzer, I., Te Wierik, S., Porkka, M., Staal, A., Jaramillo, F., Dahlmann, H., Singh, C., Greve, P., Gerten, D., Keys, P. W., Gleeson, T., Cornell, S. E., Steffen, W., Bai, X. and Rockström, J. 2022. A planetary boundary for green water. *Nature Reviews Earth & Environment*, Vol. 3, No. 6, pp. 380–392. doi.org/10.1038/s43017-022-00287-8.

Wheeler, S., Ringler, C. and Garrick, D. 2023. Carbon's social cost can't be retrofitted to water. *Nature*, Vol. 617, No. 7960, pp. 252–252. doi.org/10.1038/d41586-023-01564-2.

White, G. F. 1957. A perspective of river basin development. *Law and Contemporary Problems*, Vol. 22, No. 2, pp. 157–187.

Whittington, D., Sadoff, C. and Allaire, M. 2013. *The Economic Value of Moving Toward a More Water Secure World*. Technical Paper No. 18. Stockholm, Global Water Partnership (GWP). www.gwp.org/globalassets/global/toolbox/publications/background-papers/18-the-economic-value-of-moving-toward-a-more-water-secure-world-2013.pdf.

Woodhouse, P. and Muller, M. 2017. Water governance – An historical perspective on current debates. *World Development*, Vol. 92, pp. 225–241. doi.org/10.1016/j.worlddev.2016.11.014.

World Bank Group. 2016. *High and Dry: Climate Change, Water, and the Economy*. Washington, World Bank. http://hdl.handle.net/10986/23665. Licence: CC BY 3.0 IGO.

Wutich, A., Thomson, P., Jepson, W., Stoler, J., Cooperman, A. D., Doss-Gollin, J., Jantrania, A., Mayer, A., Nelson-Nuñez, J., Walker, W. S. and Westerhoff, P. 2023. MAD water: Integrating modular, adaptive, and decentralized approaches for water security in the climate change era. *Wiley Interdisciplinary Reviews (WIREs): Water* Vol. 10, No. 6, Article e1680. doi.org/10.1002/wat2.1680.

Xie, L., Xu, L. and Yu, Q. 2023. Benefit sharing in international rivers: A Q-methodology study of regional understanding and perception in Asia. *PLoS ONE,* Vol. 18, No. 1, Article e0280625. doi.org/10.1371/journal.pone.0280625.

Yu, W. 2008. *Benefit Sharing in International Rivers: Findings from the Senegal River Basin, the Columbia River Basin, and the Lesotho Highlands Water Project*. Washington, World Bank. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/159191468193140438/benefit-sharing-in-international-rivers-findings-from-the-senegal-river-basin-the-columbia-river-basin-and-the-lesotho-highlands-water-project.

Chapter 10

Science, technology and information

WWAP
Matthew England and Richard Connor

With contribution from: Tommaso Abrate (WMO)

A central pillar of informing better technical and management decisions is the availability of accurate data and information (UNESCO/UN-Water, 2020). Advances in science and technology have generated an unprecedented volume of data and information regarding the state of water resources and the operational effects of management interventions at the global, regional, national, river basin and field level. Where available and when accessible, this increased level of knowledge (i.e. data and information) has been used to inform and improve policy development, operational water management decisions and technical interventions.

Real-time data and information covering relatively short timescales (e.g. minute to hour) are particularly useful for operational decisions such as early warning systems, and for managing infrastructure to mitigate flood risk. Similarly, mid-to-long-term data (e.g. intra- and inter-annual) have provided insights to support the strategic design of water infrastructure and scenario-based planning. Such advances have in turn promoted prosperity and peace within societies through the expansion of the irrigation area, the increase in agricultural production as exemplified by the Green Revolution, better access to drinking water and sanitation, improved disaster risk reduction, and the introduction of water-efficient industrial processes.

Real-time data and information covering relatively short timescales are particularly useful for operational decisions

However, there still exists a significant lack of historical and up-to-date data and information on surface and groundwater, soil moisture, and associated hydro-meteorological parameters. Furthermore, historical (time-series) data become less reliable due to increasing climate variability (and change), posing challenges to the planning and design of water infrastructure (IPCC, 2022; Milly et al., 2008). This hinders progress towards Sustainable Development Goals (SDGs), particularly the targets of SDG 6, on water, and also other goals such as SDG 2 on zero hunger. Where data and information do exist, forthcoming and transparent sharing between user groups can be problematic in some cases, particularly in the case of transboundary data between riparians (United Nations, 2023).

The SDG 6 Global Acceleration Framework identifies data and information as a key component to build trust through data generation, validation, standardization and information exchange for decision-making and accountability in water management (UN-Water, 2020). Progress towards SDG 6 targets is only comprehensively reported for drinking water and sanitation, with only rough indications of progress for indicators such as water stress, water use efficiency, transboundary cooperation and integrated water resources management (IWRM), leaving 5 of the 11 indicators with little (if any) quantified information on progress. These data gaps are largely due to monitoring and reporting deficiencies (United Nations, 2023). In 2023, the UN-Water Integrated Monitoring Initiative for SDG 6 initiated a renewed data drive, requesting data and offering associated capacity-building.

10.1 Science, technology and innovation

Advances in science have played a critical role in technological development and innovation within the water sector. This has led to the development of innovative tools and approaches to measure and monitor parameters of the hydrosphere. These include, but are not limited to, information and communication technologies; earth observation and space technology through the deployment of satellites and remote sensing; advanced sensor technology to monitor hydrological systems; the rise of citizen science supported by low-cost technologies; and the application of 'big data' analytics (UNESCO/UN-Water, 2020).

Artificial intelligence (AI) has been proposed to help address challenges across water supply, sanitation and hygiene (WASH) systems, water use in agriculture and industry, and water resources management. It is claimed that AI has the ability to enhance supply insights into catchment management, emergency response, wastewater treatment plants and distribution networks, operations and maintenance, and demand management (Richards et al., 2023). However, the performance of any AI tool also requires data. The benefits of AI are caveated with the warning that the impacts of this nascent technology remain largely unknown, with the potential to trigger serious and unexpected problems. These include system-wide compromise owing to design errors, malfunction and cyber-attacks (Box 10.1), which in turn could lead to critical infrastructure failure in a worst-case scenario. Mitigation strategies to alleviate risks associated with AI include addressing gaps in foundational infrastructure and digital literacy; establishing institutional, software and hardware mechanisms for trustworthy AI; and developing detailed risk–benefit analyses (Richards et al., 2023).

Water consumption by information technology companies[49] has significantly increased in recent years, by up to a third. A major share of this is attributed to the development of AI and related technologies. Large volumes of water are used in the liquid cooling systems of computers that run AI programmes, in addition to the energy required to power the equipment. It is estimated that AI currently requires 500 ml of water to answer 10–50 queries,[50] dependent on the weather and season, and energy generation water use efficiency. The simulated training of GPT-3 in state-of-the-art data centres in the United States of America (USA) consumes and estimated 700,000 l of water (Li et al., 2023). The water consumption of AI should be considered within allocation arrangements to reach equitable solutions between users, particularly if current levels of water use are maintained or increase within water-scarce basins.

10.2 Data and information

Water resource systems cannot be effectively designed and operated unless adequate data and information are available concerning location, quantity, quality, temporal variability and demand (Stewart, 2015). Reliable hydrological data are needed to adaptively manage resources, to calibrate remotely sensed observations, and for modelling (Wilby, 2019). However, as highlighted throughout previous *United Nations World Water Development Reports,* there is a significant lack of data and information to inform the sustainable management of water. Government agencies tasked with resource monitoring and management often lack the capacity to collect data and generate information required to address water-related economic and social challenges (United Nations, 2023). This represents a significant challenge globally (UNESCO/UN-Water, 2020; Cantor et al., 2018; Stewart, 2015).

Where they do exist, data and information are often arranged in thematic or sectorial categories that have not significantly changed in recent decades (e.g. data and information are often compartmented for flood management, river discharge, water quality), without considering linkages (Wilby, 2019). Management challenges are exacerbated by climate change and associated hydro-meteorology variations, so that historical hydrological records can no longer be accurately used to predict future conditions (IPCC, 2022; Wagener et al., 2010; Milly et al., 2008). It is in societies' best interest that governments provide data though open-access platforms, without costs to users, and promote their dissemination (United Nations, 2023). Private companies should disclose relevant data and information concerning surface – and most notably sub-surface – water-related parameters to the authorities responsible for water management (United Nations, 2022). However, this requires relevant legislation at the national and potentially at the transboundary level.

[49] Microsoft disclosed that its global water consumption spiked 34% from 2021 to 2022 (Microsoft, 2022), while Google reported a 20% growth in water use in the same period (Google, 2023).

[50] Except in Ireland where it can support 70 queries, owing to the cooler climate and relatively more water-efficient energy generation.

Box 10.1 Risks associated with cyber-attacks

The number of reported cyber-attacks on critical water infrastructure – including drinking water supply, wastewater and sewerage treatment, dams and canals – has increased in recent years (Tuptuk et al., 2021). These risks are expected to rise owing to the development and increasing uptake of cyber-physical water systems, that integrate computational and physical capabilities in order to control and monitor processes. In the past, water system security was achieved largely through physical isolation, limiting access to control components. However, with the emergence of the Internet of Things,[a] water systems are increasingly using a smart systems philosophy, incorporating analytics into industrial control systems to improve the sensing and control capacity (Bello et al., 2023; Tuptuk et al., 2021).

"Cyber-attacks could be launched remotely by employing command and control techniques to interrupt the system's performance and provide access to illegitimate parties to critical and confidential information. Moreover, in more severe cases, such attacks can even cause physical impairment to the system's structure. Furthermore, such attacks can hamper the water quality by changing the treatment systems or suppressing contamination warnings by affecting water quality sensors" (Bello et al., 2023, p. 2). The implications on society are potentially serious and multi-faceted. Cyber-attacks may affect services of critical infrastructure for drinking water, wastewater treatment and sewerage, agricultural production and food systems, energy generation, navigation, and disaster management (including floods and droughts) (Gleick, 2006; Amin et al., 2012; Copeland, 2010).

Governments are developing cyber-security plans to safeguard critical water infrastructure. To mitigate risks, personnel needs to be trained to assess and identify threats to water infrastructure (Bello et al., 2023; Moraitis et al., 2020; Hassanzadeh et al., 2020; Adepu and Mathur, 2016). Measures include regular cyber-security assessments and incident response plans, vigilant monitoring of water system treatment processes, along with access controls encryption, firewalls, anti-virus measures, back-ups and multi-factor authentication (Waterfall, 2023).

[a] The Internet of Things describes devices with sensors, processing ability, software and other technologies that connect and exchange data with other devices and systems over the Internet or other communications networks.

10.2.1 Data sources

Hydrological data can be obtained from a number of sources. These include in-situ measurements through monitoring networks operated by governments, and in some cases operated by other water users such as hydropower companies and private farms. Data are also obtained from model estimation and administrative collection (e.g. regulation data such as permits or census data) (Bureau of Meteorology, 2017). Data can also be generated by other sources, such as earth observations from satellites (Landerer and Swenson, 2012), sensor networks, citizen data and social media (UNESCO/UN-Water, 2020). Considerable amounts of data are still held in paper archives that have yet to be digitized, particularly government records in low-income countries; but also in high-income countries when it comes to historical hydro-meteorological variability (Burt and Hawkins, 2019). Once data are collected and analysed, they can be transformed into the information that is required to support management decisions and policy development processes.

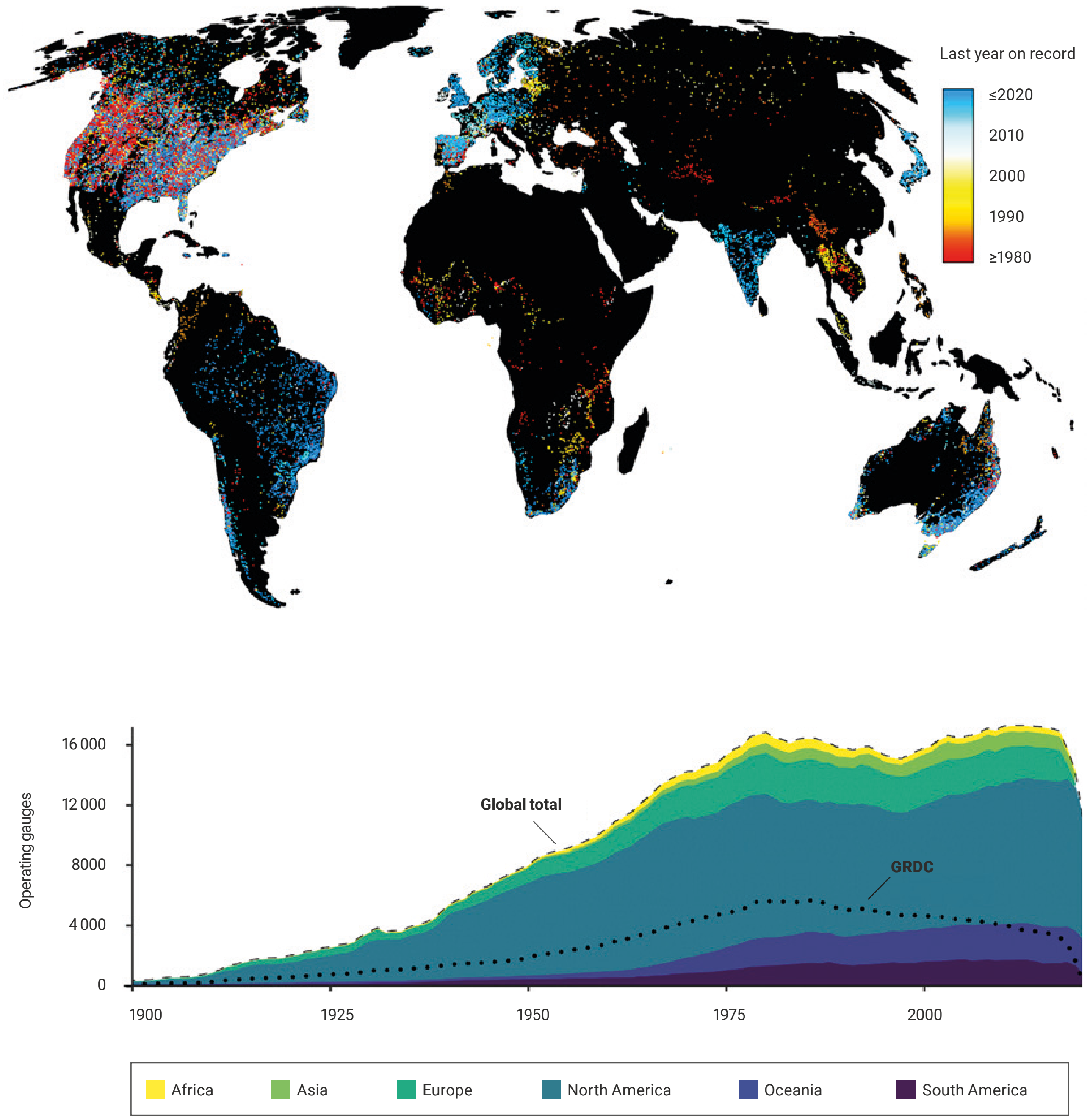
Global overview of data/information

Although some hydrological data are collected in nearly all major river basins around the world, their quality, distribution, availability and accessibility are highly variable; as well as the parameters monitored (WMO, 2022). In many low-income countries, hydrological data are largely inadequate. Data on water quantity and especially water quality remain sparse, due in large part to weak monitoring and reporting capacity. This is especially the case in many low-income countries in Africa and Asia (United Nations, 2023).

There are geographically large regions that lack ground measurements of fundamental water balance components (e.g. precipitation, evapotranspiration and changes in ice, lakes, wetlands, soil, or groundwater storage). Observational network densities are notably sparse in the Arctic, Sub-Saharan Africa (with the exception of South Africa), Central Asia, the Pacific Islands and South America (Wilby, 2019). A significant proportion of countries are characterized by very limited or inexistent groundwater monitoring networks, owing to the cost of development, operation and maintenance (IGRAC, 2020). Accurate data on soils are even more sparse, significantly limiting knowledge of how water soil content and storage impact agricultural productivity (Kendzior et al., 2022).

Gauging stations are distributed unevenly and sparsely across rivers globally (WMO, 2022). They do not capture the full extent of hydrological variability and anthropogenic influences (Krabbenhoft et al., 2022). The concentration of river gauging stations is significantly higher in Europe, North America and Oceania, relative to other regions (Figure 10.1). Gauging stations are distributed relatively sparsely within basins characterized by high annual river discharge, and rivers characterized by non-perennial flow regimes (Krabbenhoft et al., 2022). There is also a disconnect between the number of gauging stations in basins with a high seasonal variability in water availability, where it is important to monitor large inter-annual hydrological fluxes (Figure 10.2). There is a need to increase the number of gauging stations, particularly in under-represented basins and environmentally vulnerable areas, to capture the full extent of hydrological variability and anthropogenic influences.

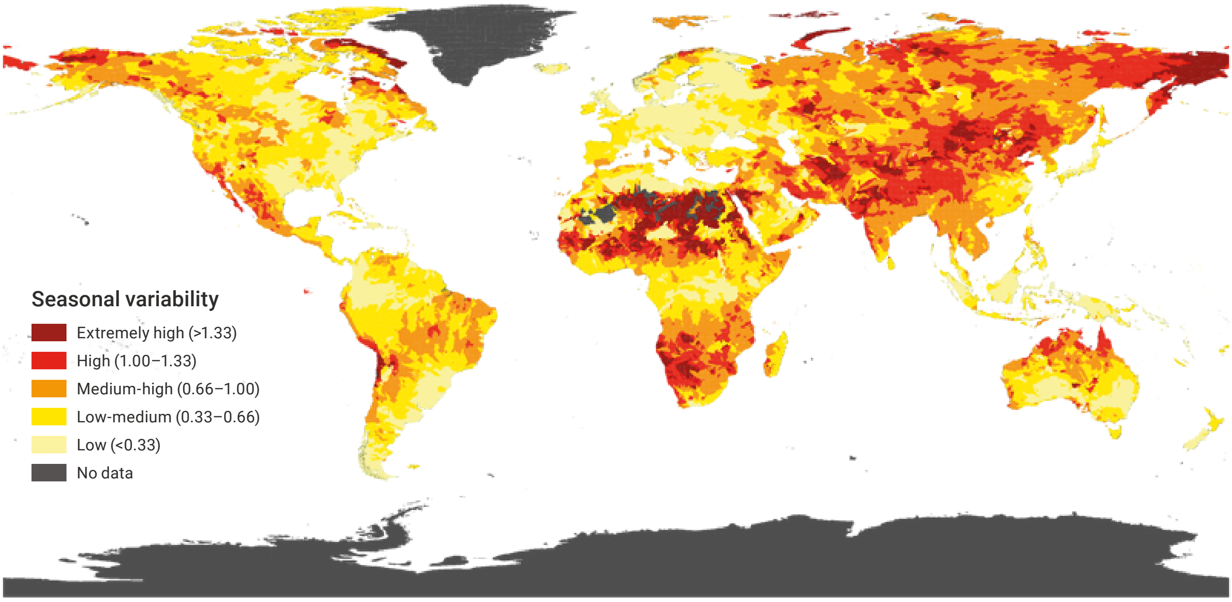
Figure 10.1 Global distribution of river gauging stations



Note: GRDC: Global Runoff Data Centre

Source: Adapted Riggs et al. (2023, fig. 2, p. 5). Licence CC BY 4.0.

Figure 10.2 Seasonal variability in water availability



Note: Seasonal variability measures the average within-year variability of available water supply, including both renewable surface and groundwater supplies. Higher values indicate wider variations of available supply within a year.

Source: WRI (2019). Licence CC BY 4.0.

It is generally recognized that some of the most data-sparse regions are also the most vulnerable to hydroclimatic hazards (Wilby, 2019). High-altitude regions and fragile states are particularly under-monitored. For instance, high-altitude areas of the Hindu Kush Himalaya lack long-term observational data, and the available data suffer from large inconsistencies and from high inhomogeneity. This hinders understanding of system dynamics, and is "*a major barrier to designing context-specific interventions. This […] deters the addressing [of] challenges faced by mountain communities scale economics, access to infrastructure and resources, poverty levels and capability gaps, and also thwarts the large-scale replication of successful innovative demonstration/pilot projects that have been implemented in the region*" (Wester et al., 2019, pp. 168–169).

Governments are developing cyber-security plans to safeguard critical water infrastructure

Even where data exist, records are often incomplete due to a lack of resources for personnel and equipment, or because they were lost due to inadequate data management practices, all of which are likely to be exacerbated under conditions of conflict. Furthermore, there is potential for erroneous issues due to site, instrument or observer changes; data may be corrupted at any point in the information flow or held in inaccessible formats (Wilby et al., 2017).

Responses to increase data collection and monitoring

As described by Wilby (2019), approaches to improve hydrological data collection and monitoring include the installation of equipment at strategically important places (known as sentinel locations) where hydrological variations are most likely to be detected (Fowler and Wilby, 2010). Evidence suggests that at high elevation, sites are warming more rapidly than the global average (Pepin et al., 2015), although this might only hold true up to 5,000 metres (Gao, et al., 2018). Hydrological assessments are urgently required in mountain regions; for instance, in the Himalaya Hindu Kush region, where mountain waters support the agricultural livelihoods, and water and energy requirements of over two billion people (Wester et al., 2019; Immerzeel et al., 2010).

Insights regarding data-sparse regions can be gained from several approaches. Basic hot-spot sensitivity analyses can identify communities most at risk, or inform the design of future hydro-meteorological network expansions (Wilby, 2019). Temporal data-scaling can extrapolate to sub-daily or sub-hourly precipitation levels for engineering design, in those situations where daily data exist (Courty et al., 2019). Alternatively, geostatistical techniques can be used to blend fragments of in-situ field data with remotely sensed information (Wilby and Yu, 2013), including proxies for hydrological variables (Najmaddin et al., 2017) to run hydrological models (Samaniego et al., 2011). Comprehensive assessments are needed to compare temporal and spatial variations in remotely sensed, model and ground-based hydro-meteorological data (Sun et al., 2018).

The development of high-resolution gravity-based methods could assess water variability at whole catchment scales, complementing or providing an alternative to river gauging techniques (Gouweleeuw et al., 2017). Remote sensing data may offer advantages to data-sharing between riparian countries not sharing data. Satellite imagery is impartial and can facilitate the incorporation of scientific data into decision-making. Remote sensing can aid in data collection, aggregation, monitoring, and information sharing (UNESCO/UN-Water, 2020; Wilby, 2019).

In-situ hydrological monitoring is often inadequate or absent in low-income countries

In-situ hydrological monitoring is often inadequate or absent in low-income countries. This is often due to insufficient technical capacity to operate and maintain equipment, particularly in remote locations, underpinned by low levels of funding to install, maintain and expand observation networks. In such cases, alternative approaches using low-cost, locally available technology (e.g. staff gauges and local observers), as well as existing capacity can be considered to collect and manage data. Citizen science is the involvement of citizens in scientific research and data gathering (Njue et al., 2019; Bonney et al., 2009). It represents an invaluable opportunity for both data collection and public participation in water-related projects (Hegarty et al., 2021). Over recent years, significant volumes of data and information on water science and management have been collected (Buytaert et al., 2014; Follett and Strezov, 2015). For instance, citizen science has been used to address the lack of water quality data in relation to SDG Indicator 6.3.2 (Quinlivan et al., 2020). Beyond producing data, citizen science is also recognized to have broader environmental, social, economic and political benefits (Hecker et al., 2018). These include strengthening participatory decision-making processes, local leadership and capacity development (Njue et al., 2019). Capacity-building through externally sourced training, in order to establish operation and maintenance of hydrological monitoring systems within data-sparse regions, has occurred historically in low-income countries with varied levels of success (Kirschke et al., 2020).

Data- and information-sharing

Forthcoming and transparent sharing of data and information is essential to promote effective water management. Transparent sharing includes data and metadata exchange, preferably within international standards; as well as open-access and open-source platforms and technologies.[51] However, the level of sharing varies significantly. Where data and information are considered sensitive (politically, economically or otherwise), sharing is often limited or non-existent. Data and information can be withheld or manipulated to serve one actor's interest over that of others. There can also be significant time lags between data collection and sharing, which could hamper operational decision-making.

Data-sharing can be limited between government and non-government actors. The private sector can limit data-sharing by declaring certain data as 'sensitive' (e.g. a security risk) to protect business interest, for instance, regarding infrastructure development, domestic water supply or agriculture projects. Lack of data-sharing is also reported by private

[51] Examples include the open-access platforms maintained by FAO, such as: FAOSTAT, AQUASTAT and WaPOR.

sector investment companies engaged in large-scale land acquisition in some countries (Dell'Angelo et al., 2018; Rulli et al., 2013; Mehta et al., 2012). Irrigation is often employed on land acquired to boost agricultural productivity, where data regarding the volume of increased water withdrawn are often not collected or shared (Rulli et al., 2013).

There is a growing call for the private sector to share data with governments and other actors when a project contract expires, albeit with security caveats considered (United Nations, 2022; Rulli et al., 2013). Furthermore, environmental impact assessment data within countries that are targeted for land acquisition are found to be lacking (Dell'Angelo et al., 2018). Data-sharing can also be limited between and within government ministries and departments, which are often characterized by ineffective communication between and within departments and ministries, along with competition for project funding.

Data- and information-sharing between riparians in transboundary basins is a long-standing issue of concern. In an assessment of transboundary river basins in Africa, Asia, Europe and North America, a study found data-sharing to be below the targets established at basin level and internationally[52] (IWMI, 2021). Although a reasonable proportion of river basins exchange some operational data, the breadth of exchange is often limited and irregular. Data-sharing is found more likely to take place if it responds to a particular operational need and serves practical uses, such as to minimize flood risks or to manage transboundary infrastructure (e.g. a reservoir) between riparians. This finding concurs with a recent study that found that the level of operational data-sharing at the international basin level is steadily increasing (WMO, 2022). Despite SDG Indicator 6.5.2 promoting transboundary cooperation for IWRM, there is no single global hydrological monitoring system. Instead, there is a proliferation of networks designed and operated by government and non-government actors for specific uses and at different spatial scales, covering a range of parameters and data types. There is a need to strengthen basin-level data exchange between actors, through river basin organizations or other relevant organizations.

10.3 Conclusions

It is widely acknowledged that more and better data and information are required to inform better water management decisions and policy development. Advances in science and technology have expanded the potential to monitor the hydrosphere in greater scope and detail, thereby increasing global and local knowledge bases.

The shared availability of credible and trusted data is fundamental to building confidence between water users; at the transboundary level, and within nations and river basins. This in turn helps effective and equitable water management, and promotes prosperity and peace within society. Where available and accessible, data and information empower the user to make an evidence-based informed decision. However, further advances in science and technology, delivering better and more data alone, will not necessarily improve decision-making and policy development (WaterAid, 2019; Kumpel et al., 2020). Actors and water users make decisions and develop policies based on a multitude of factors. These include but are by no means limited to socio-political, economic, technical, administrative and other factors. Whether in abundance, lacking or in secrecy, data and information can be used in a multitude of ways.

[52] The 1992 United Nations Economic Commission for Europe's *Convention on the Protection and Use of Transboundary Watercourses and International Lakes* (UNECE, 1992); and the *United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses* (General Assembly of the United Nations, 1997).

References

Adepu, S. and Mathur, A. 2016. An investigation into the response of a water treatment system to cyber attacks. *2016 IEEE 17th International Symposium on High Assurance Systems Engineering (HASE)*. 7–9 January 2016, Orlando, Fla. IEEE. doi.org/10.1109/HASE.2016.14.

Amin, S., Litrico, X., Sastry, S. and Bayen, A. M. 2012. Cyber security of water SCADA systems—Part I: Analysis and experimentation of stealthy deception attacks. *IEEE Transactions on Control Systems Technology*, Vol. 21, No. 5, pp.1963–1970. doi.org/10.1109/TCST.2012.2211873.

Bello, A., Jahan, S., Farid, F. and Ahamed, F. 2023. A systemic review of the cybersecurity challenges in Australian water infrastructure management. *Water*, Vol. 15, Article 168. doi.org/10.3390/w15010168.

Bonney, R., Ballard, H., Jordan, R., McCallie, E., Phillips, T., Shirk, J. and Wilderman, C. C. 2009. *Public Participation in Scientific Research: Defining the Field and Assessing its Potential for Informal Science Education.* A CAISE Inquiry Group Report. Washington, Centre for Advancement of Informal Science Education (CAISE). files.eric.ed.gov/fulltext/ED519688.pdf.

Bureau of Meteorology. 2017. *Good Practice Guidelines for Water Data Management Policy: World Water Data Initiative*. Melbourne, Australia, Bureau of Meteorology. www.bom.gov.au/water/about/publications/document/Good-Practice-Guidelines-for-Water-Data-Management-Policy.pdf.

Burt, S. and Hawkins, E. 2019. Near-zero humidities on Ben Nevis, Scotland, revealed by pioneering 19th-century observers and modern volunteers. *International Journal of Climatology*, Vol. 39, No. 11, pp. 4451–4466. doi.org/10.1002/joc.6084.

Buytaert, W., Zulkafli, Z., Grainger, S., Acosta, L., Alemie, T. C., Bastiaensen, J., De Bièvre, B., Bhusal, J., Clark, J., Dewulf, A., Foggin, M., Hannah, D. M., Hergarten, C., Isaeva, A., Karpouzoglou, T., Pandeya, B., Paudel, D., Sharma, K., Steenhuis, T., Tilahun, S., Van Hecken, G. and Zhumanova, M. 2014. Citizen science in hydrology and water resources: Opportunities for knowledge generation, ecosystem service management, and sustainable development. *Frontiers in Earth Science*, Vol. 2. doi.org/10.3389/feart.2014.00026.

Cantor, A., Kiparsky, M., Kennedy, R., Hubbard, S., Bales, R., Cano Pecharroman, L., Guivetchi, K., McCready, C. and Darling, G. 2018. *Data for Water Decision Making: Informing the Implementation of California's Open and Transparent Water Data Act through Research and Engagement*. Berkeley, Calif., Center for Law, Energy & the Environment, UC Berkeley School of Law. doi.org/10.15779/J28H01.

Copeland, C. 2010. *Terrorism and Security Issues Facing the Water Infrastructure Sector.* Washington, Library of Congress, Congressional Research Service.

Courty, L. G., Wilby, R. L., Hillier, J. K. and Slater, L. J. 2019. Intensity-duration-frequency curves at the global scale. *Environmental Research Letters*, Vol. 14, No. 8. doi.org/10.1088/1748-9326/ab370a.

Dell'Angelo, J., Rulli, M. C. and D'Odorico, P. 2018. The global water grabbing syndrome. *Ecological Economics*, Vol. 143, pp. 276–285. doi.org/10.1016/j.ecolecon.2017.06.033.

Follett, R. and Strezov, V. 2015. An analysis of citizen science based research: Usage and publication patterns. *PLoS ONE*, Vol. 10, No. 11, Article e0143687. doi.org/10.1371/journal.pone.0143687.

Fowler, H. J. and Wilby, R. L. 2010. Detecting changes in seasonal precipitation extremes using regional climate model projections: Implications for managing fluvial flood risk. *Water Resources Research*, Vol. 46, No. 3. doi.org/10.1029/2008WR007636.

Gao, Y., Chen, F., Lettenmaier, D. P., Xu, J., Xiao, L. and Li, X. 2018. Does elevation-dependent warming hold true above 5000 m elevation? Lessons from the Tibetan plateau. *npj Climate and Atmospheric Science*, Vol. 1, Article 19. doi.org/10.1038/s41612-018-0030-z.

General Assembly of the United Nations. 1997. *Convention on the Law of the Non-navigational Uses of International Watercourses*. Report of the Sixth Committee convening as the Working Group of the Whole, 11 April 1997. Fifty-first session. A/51/869. digitallibrary.un.org/record/233155?ln=en.

Gleick, P. H. 2006. Water and terrorism. *Water Policy*, Vol. 8, No. 6, pp. 481–503. doi.org/10.2166/wp.2006.035.

Google. 2023. *Environmental Report 2023*. Google. www.gstatic.com/gumdrop/sustainability/google-2023-environmental-report.pdf.

Gouweleeuw, B. T., Kvas, A., Grüber, C., Gain, A. K., Mayer-Gürr, T., Flechtner, F. and Güntner, A. 2017. Daily GRACE gravity field solutions track major flood events in the Ganges-Brahmaputra Delta. *Hydrology and Earth System Sciences*, Vol. 22, No. 5, pp. 2867–2880. doi.org/10.5194/hess-2016-653.

Hassanzadeh, A., Rasekh, A., Galelli, S., Aghashahi, M., Taormina, R., Ostfeld, A. and Banks, M. K. 2020. A review of cybersecurity incidents in the water sector. *Journal of Environmental Engineering*, Vol. 146, No. 5. doi.org/10.1061/(ASCE)EE.1943-7870.0001686.

Hecker, S., Haklay, M., Bowser, A., Makuch, Z., Vogel, J. and Bonn, A. 2018. Innovation in open science, society and policy – setting the agenda for citizen science. S. Hecker, M. Haklay, A. Bowser, Z. Makuch, J. Vogel and A. Bonn (eds.), *Citizen Science: Innovation in Open Science, Society and Policy.* London, UCL Press, pp. 1–23.

Hegarty, S., Hayes, A., Regan, F., Bishop, I. and Clinton, R. 2021. Using citizen science to understand river water quality while filling data gaps to meet United Nations Sustainable Development Goal 6 objectives. *Science of The Total Environment*, Vol. 783, Article 146953. www.sciencedirect.com/science/article/pii/S0048969721020234?via%3Dihub.

IGRAC (International Groundwater Resources Assessment Centre). 2020. *National Groundwater Monitoring Programmes: A Global Overview of Quantitative Groundwater Monitoring Networks*. Delft, The Netherlands, IGRAC. www.un-igrac.org/stories/national-groundwater-monitoring-programmes.

Immerzeel, W. W., Van Beek, L. P. H. and Bierkens, M. F. P. 2010. Climate change will affect the Asian water towers. *Science*, Vol. 328, No. 5984, pp. 1382–1385. doi.org/10.1126/science.1183188.

IPCC (Intergovernmental Panel on Climate Change) 2022. *Climate Change 2022: Impacts, Adaptation, and Vulnerability.* Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D. C. Roberts, M. Tignor, E. S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge, UK/New York, Cambridge University Press. www.ipcc.ch/report/ar6/wg2/.

IWMI (International Water Management Institute). 2021. *Data Sharing in Transboundary Waters: Current Extent, Future Potential and Practical Recommendations*. IWMI Water Policy Brief 43. Colombo, IWMI. doi.org/10.5337/2021.232.

Kendzior, J., Raffa, D. W. and Bogdanski, A. 2022. *The Soil Microbiome: A Game Changer for Food and Agriculture*. Executive Summary for Policymakers and Researchers. Rome, FAO (Food and Agriculture Organization of the United Nations). www.fao.org/3/cc0717en/cc0717en.pdf.

Kirschke, S., Avellán, T., Bärlund, I., Bogardi, J. J., Carvalho, L., Chapman, D., Dickens, C. W. S., Irvine, K., Lee, S. B., Mehner, T. and Warner, S. 2020. Capacity challenges in water quality monitoring: Understanding the role of human development. *Environmental Monitoring Assessment*, Vol. 192, Article 298. doi.org/10.1007/s10661-020-8224-3.

Krabbenhoft, C. A., Allen, G. H., Lin, P., Godsey, S. E., Allen, D. C., Burrows, R. M., DelVecchia, A. G., Fritz, K. M., Shanafield, M., Burgin, A. J., Zimmer, M. A., Datry, T., Dodds, W. K., Jones, C. N., Mims, M. C., Franklin, C., Hammond, J. C., Zipper, S., Ward, A. S., Costigan, K. H., Beck, H. E. and

Olden, J. D. 2022. Assessing placement bias of the global river gauge network. *Nature Sustainability*, Vol. 5, No. 7, pp. 586–592. doi.org/10.1038/s41893-022-00873-0.

Kumpel, E., MacLeod, C., Stuart, K., Cock-Esteb, A., Khush, R. and Peletz, R. 2020. From data to decisions: Understanding information flows within regulatory water quality monitoring programs. *npj Clean Water*, Vol. 3, Article 38. doi.org/10.1038/s41545-020-00084-0.

Landerer, F. W. and Swenson, S. C. 2012. Accuracy of scaled GRACE terrestrial water storage estimates. *Water Resources Research*, Vol. 48, No. 4, Article W04531. doi.org/10.1029/2011WR011453.

Li, P., Yang, J., Islam, M. A. and Ren, S. 2023. Making AI less "thirsty": Uncovering and addressing the secret water footprint of AI models. doi.org/10.48550/arXiv.2304.03271.

Mehta, L., Veldwisch, G. J. and Franco, J. 2012. Water grabbing? Focus on the (re)appropriation of finite water resources. *Water Alternatives*, Vol. 5, No. 2, pp. 193–207.

Microsoft. 2022. *Environmental Sustainability Report 2022. Enabling Sustainability for our Company, our Customers, and the World*. Microsoft. www.microsoft.com/en-us/corporate-responsibility/sustainability/report.

Milly, P. C. D., Betancourt, J., Falkenmark, M., Hirsch, R. M., Kundzewicz, Z. W., Lettenmaier, D. P. and Stouffer, R. J. 2008. Stationarity is dead: Whither water management? *Science*, Vol. 319, No. 5863, pp. 573–574. doi.org/10.1126/science.1151915.

Moraitis, G., Nikolopoulos, D., Bouziotas, D., Lykou, A., Karavokiros, G. and Makropoulos, C. 2020. Quantifying failure for critical water infrastructures under cyber-physical threats. *Journal of Environmental Engineering*, Vol. 146, No. 9. doi.org/10.1061/(ASCE)EE.1943-7870.0001765.

Najmaddin, P. M., Whelan, M. J. and Balzter, H. 2017. Estimating daily reference evapotranspiration in a semi-arid region using remote sensing data. *Remote Sensing*, Vol. 9, No. 8, Article 779. doi.org/10.3390/rs9080779.

Njue, N., Stenfert Kroese, J., Gräf, J., Jacobs, S. R., Weeser, B., Breuer, L. and Rufino, M. C. 2019. Citizen science in hydrological monitoring and ecosystem services management: State of the art and future prospects. *Science of the Total Environment*, Vol. 693, Article 133531. doi.org/10.1016/j.scitotenv.2019.07.337.

Pepin, N., Bradley, R. S., Diaz, H. F., Baraër, M., Caceres, E. B., Forsythe, N., Fowler, H., Greenwood, G., Hashmi, M. Z., Liu, X. D., Miller, J. R., Ning, L., Ohmura, A., Palazzi, E., Rangwala, I., Schöner, W., Severskiy, I., Shahgedanova, M., Wang, M. B., Williamson, S. N. and Yang, D. Q. 2015. Elevation-dependent warming in mountain regions of the world. *Nature Climate Change*, Vol. 5, pp. 424–430. www.nature.com/articles/nclimate2563.

Quinlivan, L., Chapman, D. V. and Sullivan, T. 2020. Applying citizen science to monitor for the Sustainable Development Goal Indicator 6.3.2: A review. *Environmental Monitoring and Assessment*, Vol. 192, Article 218. doi.org/10.1007/s10661-020-8193-6.

Richards, C. E., Tzachor, A., Avin, S. and Fenner, R. 2023. Rewards, risks and responsible deployment of artificial intelligence in water systems. *Nature Water*, Vol. 1, pp. 422–432. doi.org/10.1038/s44221-023-00069-6.

Riggs, R. M., Allen, G. H., Wang, J., Pavelsky, T. M., Gleason, C. J., David, C. H. and Durand, M. 2023. Extending global river gauge records using satellite observations. *Environmental Monitoring and Assessment,* Vol. 18, No. 6, Article 4027. doi.org/10.1088/1748-9326/acd407.

Rulli, M. C., Saviori, A. and D'Odorico, P. 2013. Global land and water grabbing. *Proceedings of the National Academy of Sciences (PNAS)*, Vol. 110, No. 3, pp. 892–897. doi.org/10.1073/pnas.1213163110.

Samaniego, L., Kumar, R. and Jackisch, C. 2011. Predictions in a data-sparse region using a regionalized grid-based hydrologic model driven by remotely sensed data. *Hydrology Research*, Vol. 42, No. 5, pp. 338–355. doi.org/10.2166/nh.2011.156.

Stewart, B. 2015. Measuring what we manage: The importance of hydrological data to water resources management. *Proceedings of the International Association of the Hydrological Sciences (PIAHS)*, Vol. 366, pp. 80–85. doi.org/10.5194/piahs-366-80-2015.

Sun, Q., Miao, C., Duan, Q., Ashouri, H., Sorooshian, S. and Hsu, K.-L. 2018. A review of global precipitation data sets: Data sources, estimation, and intercomparisons. *Reviews of Geophysics*, Vol. 56, No. 1, pp. 79–107. doi.org/10.1002/2017RG000574.

Tuptuk, N., Hazell, P., Watson, J. and Hailes, S. 2021. A systematic review of the state of cyber-security in water systems. *Water*, Vol. 13, Article 81. doi.org/10.3390/w13010081.

UNECE (United Nations Economic Commission for Europe). 1992. *Convention on The Protection and Use of Transboundary Watercourses and International Lakes*. Helsinki, 17 March 1992, UNECE. unece.org/environment-policy/water/about-the-convention/introduction.

UNESCO/UN-Water (United Nations Educational, Scientific and Cultural Organization/UN-Water). 2020. *The United Nations World Water Development Report 2020: Water and Climate Change*. Paris, UNESCO. unesdoc.unesco.org/ark:/48223/pf0000372985.

United Nations. 2022. *The United Nations World Water Development Report 2022: Groundwater: Making the Invisible Visible*. Paris, United Nations Educational, Scientific and Cultural Organization (UNESCO). https://unesdoc.unesco.org/ark:/48223/pf0000380721.

_____. 2023. *The United Nations World Water Development Report 2023: Partnerships and Cooperation for Water.* Paris, United Nations Educational, Scientific and Cultural Organization (UNESCO). https://unesdoc.unesco.org/ark:/48223/pf0000384655.

UN-Water. 2020. *The Sustainable Development Goal 6 Global Acceleration Framework*. Geneva. www.unwater.org/sites/default/files/app/uploads/2020/07/Global-Acceleration-Framework.pdf.

Wagener, T., Sivapalan, M., Troch, P. A., McGlynn, B. L., Harman, C. J., Gupta, H. V., Kumar, P., Rao, P. S. C., Basu, N. B. and Wilson, J. S. 2010. The future of hydrology: An evolving science for a changing world. *Water Resources Research*, Vol. 46, No. 5. doi.org/10.1029/2009WR008906.

WaterAid. 2019. *From Data to Decisions: How to Promote Evidence-Based Decision Making through External Investments in Country-Led Monitoring Processes*. London, WaterAid. washmatters.wateraid.org/sites/g/files/jkxoof256/files/from-data-to-decisions.pdf.

Waterfall. 2023. Nine Cybersecurity Challenges for Critical Water Infrastructure. Waterfall website. https://waterfall-security.com/ot-insights-center/water-wastewater/9-cybersecurity-challenges-for-critical-water-infrastructure/. (Accessed on 27 June 2023).

Wester, P., Mishra, A., Mukherji, A., Shrestha, A. B. (eds.). 2019. *The Hindu Kush Himalaya Assessment: Mountains, Climate Change, Sustainability and People*. Cham, Switzerland, Springer International Publishing. lib.icimod.org/record/34383.

Wilby, R. L. 2019. A global hydrology research agenda fit for the 2030s. *Hydrology Research*, Vol. 50, No. 6, pp. 1464–1480. doi.org/10.2166/nh.2019.100.

Wilby, R. L. and Yu, D. 2013. Rainfall and temperature estimation for a data sparse region. *Hydrology and Earth System Sciences*, Vol. 17, No. 10, pp. 3937–3955. doi.org/10.5194/hess-17-3937-2013.

Wilby, R. L., Clifford, N. J., De Luca, P., Harrigan, S., Hillier, J. K., Hodgkins, R., Johnson, M. F., Matthews, T. K., Murphy, C., Noone, S. J., Parry, S., Prudhomme, C., Rice, S. P., Slater, L. J., Smith, K. A. and Wood, P. J. 2017. The 'dirty dozen' of freshwater science: Detecting then reconciling hydrological data biases and errors. *Wiley Interdisciplinary Reviews (WIREs): Water*, Vol. 4, No. 3, Article e1209. doi.org/10.1002/wat2.1209.

WMO (World Meteorological Organization). 2022. *State of Global Water Resources 2021.* Geneva, WMO. https://wmo.int/publication-series/state-of-global-water-resources-2021.

WRI (World Resources Institute). 2019. WRI Aqueduct website. www.wri.org/aqueduct.

Chapter 11

Education and capacity development

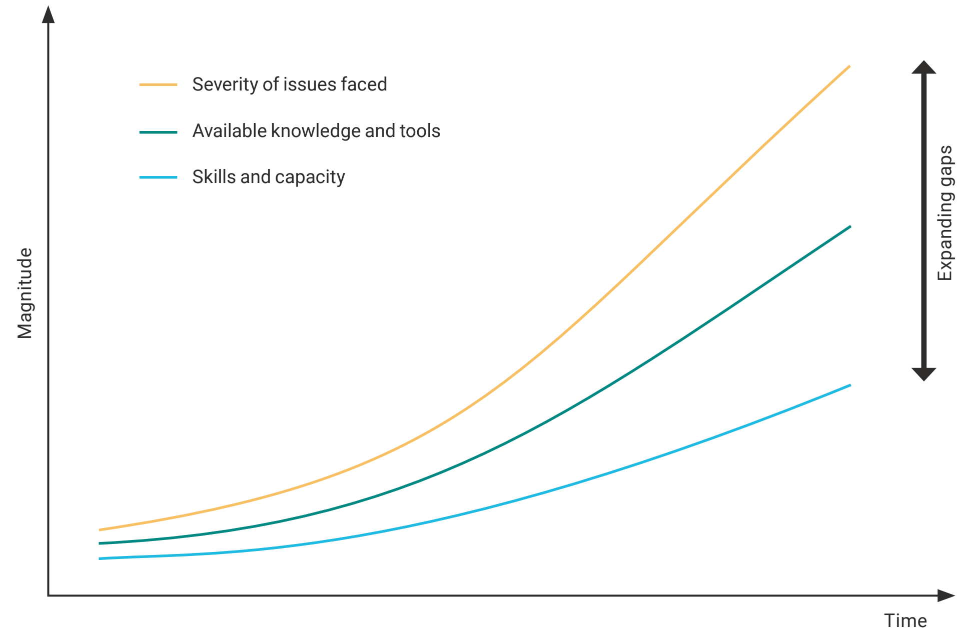
UNESCO IHP

Wouter Buytaert and Jorge Ellis

With contributions from: Susanne Schmeier (IHE Delft)

Freshwater is vital for human prosperity; yet humankind's efforts to provide clean water and sanitation for all is falling behind, as the indicators of Sustainable Development Goal (SDG) 6 show clearly (United Nations, 2023a). Education and capacity development are key to addressing this challenge. In many parts of the world, and in many developing countries in particular, water and sanitation are not optimally managed. The lack of training and relevant skills is at the heart of this issue (UNESCO, 2014). Although major advances have been made in the adoption of new technologies, the gap between the severity of water problems, the knowledge base and skill sets available to solve them is widening in many areas (Figure 11.1). This delays the adoption of new technologies for water treatment, sanitation and integrated river basin management, among others – which, in turn, leads to wasteful use of water, avoidable contamination of freshwater resources, and inappropriate levels of access to safe and clean water.

Figure 11.1
The widening gaps between the severity of water problems, and the knowledge and capacity required to address them



Source: Authors.

The gap in skills and capacity is even more pronounced on non-technological aspects of water management and governance, such as legal, policy and institutional development. These skills are essential in the context of equitable water governance, especially in complex settings such as transboundary river basins or conflict-prone regions, where resolutions may require a process of negotiation and compromise (see Chapters 7 and 9).

As argued throughout the report, the rapidly increasing pressures on global water resources heighten the risks of competition at various scales in many parts of the world. Avoiding and defusing water-related crises and conflicts will require new ways of thinking, as well as innovative and often transdisciplinary solutions and governance arrangements. Education is the catalyst to uptake and application of such new methods, technologies and behaviours. At the same time, conflicts, irrespective of whether they are triggered by water or not, often have a strong impact on education, notably through decreased access to water and sanitation facilities.

This chapter identifies some of the skills required to leverage water for prosperity and peace, and reflects on the challenges and opportunities of generating and implementing those skills to support water management for conflict prevention and dispute resolution.

11.1 Water and education in conflict situations

Conflict situations can exacerbate the impact on local livelihoods, including education, through water. Reduced access to water and sanitation services resulting from conflict may force children to drop out of school, with often a disproportionate impact on girls.

An example is provided by Gleick et al. (2020), who analyse the case of drought and water quality issues in Iraq, which contributed to violent protest throughout 2018. They describe how women and girls are the primary water collectors in Iraq, spending on average up to three hours per day on water collection (Central Statistical Organization Iraq/Kurdistan Region Statistics Office/Iraqi Ministry of Health/UNICEF, 2018). Reduced access to water supply increases this burden. This is known to have a negative impact on women's education, economic participation and safety, and may contribute to the higher secondary school dropout rate of girls compared to boys (UNICEF/Government of Iraq, 2017). Also elsewhere, studies have shown that a reduction of one hour in water collection can increase the rate of school enrolment of girls (Koolwal and Van de Walle, 2010).

Although major advances have been made in the adoption of new technologies, the gap between the severity of water problems, the knowledge base and skill sets available to solve them is widening in many areas

The opposite also holds, as better education, political and economic participation, and safety of women is positively correlated with lower intra-state and inter-state violence (Hudson et al., 2012; Caprioli, 2000).

On the longer term, conflicts may also affect the availability of trained experts to provide education and capacity development. Local expertise may disappear through institutional decline, attrition or emigration. It also complicates training by external experts, who may be deterred from travelling to conflict regions, or find that digital infrastructure is insufficient for online training.

Yet, the impact of deteriorating access to water and sanitation during conflict situations is complex, but so is the role that water management can play in building resilience to conflict, supporting equitable sharing of scarce resources, and protecting against hydrological extremes.

11.2 Scientific and technical skills

Traditional water management curricula and training activities tend to have a strong focus on technological and engineering approaches. However, because of increasing pressures and rapidly advancing technologies, these approaches and skills need to be continually improved and updated.

This is particularly urgent in regions prone to conflict and crises, which tend to have lower water efficiency and less efficient water conservation practices (Gleick et al., 2020). Increasing water efficiency and the adoption of new technologies is often technically feasible but held back by a combination of factors. Recurrent issues include local capacity, as well as the availability and access to information and communication technologies (ICT) and measurement equipment. Conflicts may hinder the installation and proper maintenance of monitoring stations and damage existing infrastructure, leading to a lack of relevant data and observations crucial for the adequate design and operation of infrastructure.

Similarly, the further development of alternative sources of water, including reuse of grey water and water recycling, has great potential to reduce the acute water stress in conflict zones. While technical solutions often exist, their uptake is held back not only because of a lack of resources, but also because of a lack of local technical capacity to design, operate and maintain them.

11.3 Social, legal and policy skills

While the gap between technical needs and available capacity may be widening (Figure 11.1), this is even more acute in educational undertakings aimed at enhancing legal, policy and institutional frameworks to support water governance (Gleick et al., 2020).

Water problems, especially in conflict-prone situations, often involve governance challenges. They require skills that go beyond water engineering and management but can help to gain insights in the complex social, legal and policy context. For example, many river basin interventions will generate a range of benefits and disbenefits. This is particularly the case for novel approaches such as nature-based solutions (NbS) (see Chapter 6), which may increase water availability but also, for example, ecological enhancements and landscape aesthetics (WWAP/UN-Water, 2018). Stakeholders may assign very different values to those benefits (and potentially also disbenefits). Understanding these valuations and identifying the specific (dis)beneficiaries are prerequisites for finding equitable solutions. This would often require a negotiation process, which may include trade-offs, compensations and compromises (United Nations, 2021). Negotiation, policy and governance skills are essential to guide this process while minimizing the risks of escalating disputes. These include, for example, capacities to identify mutual interests, and to develop and implement benefit-sharing arrangements.

Political and legal skills required in water dispute resolution may relate to the formulation of water sharing agreements, water and food security policies and market mechanisms, the human rights to water and sanitation, and the right to a healthy environment.

Economic and financial skills are necessary to design adequate policies related to water and food security, and to measure the impact of pricing and subsidies. The lack, or improper design and implementation, of economic policies may lead to suboptimal water use and waste (see Chapter 9). One example is that of perverse subsidies, which often lead to overconsumption and inefficient water use, for example in agriculture (Myers, 1998).

Governance is often impaired in conflict-prone regions, where it requires specific policy skills, related, for example, to the reduction of corruption, the formulation of urban and rural development and gender policies, and the promotion of stakeholder engagement and inclusion.

Improving skills and capacity is also key to enable ‘bouncing forward’ after conflicts or crises. It is a necessary ingredient in order not to return to the status quo, but to use perturbations as an opportunity to build back better, i.e. to improve infrastructure, operation procedures and overall resilience.

Lastly, education and capacity-building are key in dispute mediation and resolution. The development of robust, risk-reducing solutions often requires a thorough understanding of local social and cultural contexts, including for example the cultural and religious values of water.

11.4 Public awareness and widening participation

Education remains the foundation to change human behaviour and build consensus for sustainable approaches to water services provision and resources management (UNESCO-IHP, 2022). Water education is therefore key to raising awareness of issues such as household water overuse, the effects of household chemicals on the aquatic environment, improper disposal of harmful waste, and the impact of consumption patterns on environmental pressures, such as climate change.

While classic education is a cornerstone of achieving such awareness and behaviour change, new methods of public education are emerging. Through advancing technologies, such as mobile phones and cost-effective analysis kits, citizen science holds great promise for the general public to gain first-hand experience with aspects such as water quality (provided they have access to such technology), and the impact of human activities on its deterioration.

Open science[53] is highly relevant in a water context. Lack of access to scientific data and evidence, as well as the limited abilities to interpret such evidence, often contributes substantially to a lack of trust between negotiating parties (United Nations, 2023b). This is particularly acute in contexts like industrial water contamination, where the interests of local communities are often pitched against those of interest groups with large financial resources and scientific capacity (e.g. mining activities – Bebbington et al., 2008).

In such conditions, open science can support a more transparent evidence generation that has the potential to create trust and make informed and legitimate decisions with active engagement of all stakeholders (UNESCO-IHP, 2022).

11.5 Looking forward

New opportunities are emerging to support education and capacity development in resource-constrained contexts, which is where peace and prosperity are often most at risk.

The COVID-19 pandemic has produced a wealth of online educational resources on water management, but their content needs to be further developed and adapted to include hydrological processes, technologies and social contexts of deprived regions, such as tropical drylands and informal urban developments. Access also needs to be improved, especially to bridge the digital divide that emerges from the unequal access to digital technology, such as laptops, smartphones, tablets and the internet itself. This can be done by translating training materials to local languages and preparing them for offline use. Making these materials available to trainers and extension workers can also support local offline training and capacity-building.

Novel approaches such as ‘serious games’, polycentric governance and citizen science are useful and increasingly applied to support inclusive and legitimate water governance (Ostrom, 2010). Capacity development in the use of these tools and frameworks can support the implementation of cooperative methodologies for peaceful agreements and conflict resolution.

Lastly, about one in six humans, or about 1.2 billion people, are currently aged between 15 and 24. This number is projected to grow by 7% until 2030 (United Nations, 2020). Youth engagement and education can help nurture a future generation of leaders that are committed to better water stewardship. About half of them are women and girls, who often play a key role as agents of change in water science, culture, and governance. In many places they are the primary providers or water in the household, play a key role in establishing sanitation habits and education, and possess specific knowledge and perspectives on water systems and governance. Clear empirical evidence also shows that women participation makes water projects more effective (Van Wijk-Sijbesma, 1998). Therefore, targeting them for quality education and capacity development training is an essential part of the solution to future water security and a resilient society.

---

[53] For more information, please see: www.unesco.org/en/open-science.

References

Bebbington, A., Humphreys Bebbington, D. H., Bury, J., Lingan, J., Muñoz, J. P. and Scurrah, M. 2008. Mining and social movements: Struggles over livelihood and rural territorial development in the Andes. *World Development*, Vol. 36, No. 12, pp. 2888–2905. doi.org/10.1016/j.worlddev.2007.11.016.

Caprioli, M. 2000. Gendered conflict. *Journal of Peace Research*, Vol. 37, No. 1, pp. 51–68. www.jstor.org/stable/425725.

Central Statistical Organization Iraq/Kurdistan Region Statistics Office/Iraqi Ministry of Health/UNICEF (United Nations Children's Fund). 2018. *Iraq 2018 Multiple Indicator Cluster Survey*. Survey Findings Report. https://microdata.worldbank.org/index.php/catalog/3495/download/46819.

Gleick, P., Iceland, C. and Trivedi, A., 2020. *Ending Conflicts over Water: Solutions to Water and Security Challenges*. Washington, World Resources Institute (WRI). www.wri.org/research/ending-conflicts-over-water.

Hudson, V. M., Ballif-Spanvill, B., Caprioli, M. and Emmett, C. F. 2012. *Sex and World Peace*. New York, Colombia University Press.

Koolwal, G. and Van de Walle, D. 2010. *Access to Water, Women's Work and Child Outcomes*. Policy Research Working Paper No. WPS 5302. Washington, World Bank. http://hdl.handle.net/10986/3789. Licence: CC BY 3.0 IGO."

Myers, N. 1998. Lifting the veil on perverse subsidies. *Nature*, Vol. 392, pp. 327–328. doi.org/10.1038/32761.

Ostrom, E. 2010. Polycentric systems for coping with collective action and global environmental change. *Global Environmental Change*, Vol. 20, No. 4, pp. 550–557. doi.org/10.1016/j.gloenvcha.2010.07.004.

UNESCO (United Nations Educational, Scientific and Cultural Organization). 2014. *Shaping the Future We Want*. UN Decade of Education for Sustainable Development (2005–2014). Final Report. Paris, UNESCO. https://unesdoc.unesco.org/ark:/48223/pf0000230171.

UNESCO-IHP (United Nations Educational, Scientific and Cultural Organization-Intergovernmental Hydrological Programme). 2022. *IHP-IX: Strategic Plan of the Intergovernmental Hydrological Programme: Science for a Water Secure World in a Changing Environment*. Ninth phase 2022–2029. Paris, UNESCO. https://unesdoc.unesco.org/ark:/48223/pf0000381318.

UNICEF/Government of Iraq (United Nations Children's Fund/Government of Iraq). 2017. *The Costs and Benefits of Education in Iraq: An Analysis of the Education Sector and Strategies to Maximize the Benefits of Education*. https://reliefweb.int/report/iraq/cost-and-benefits-education-iraq-analysis-education-sector-and-strategies-maximize.

United Nations. 2020. *World Youth Report 2020: Youth Social Entrepreneurship and the 2030 Agenda*. New York, United Nations. doi.org/10.18356/248b499b-en.

____. 2021. *The United Nations World Water Development Report 2021: Valuing Water*. Paris, UNESCO. https://unesdoc.unesco.org/ark:/48223/pf0000375724.

____. 2023a. *Blueprint for Acceleration: Sustainable Development Goal 6 Synthesis Report on Water and Sanitation 2023*. New York, United Nations. www.unwater.org/publications/sdg-6-synthesis-report-2023.

____. 2023b. *The United Nations World Water Development Report 2023: Partnerships and Cooperation for Water*. Paris, UNESCO. https://unesdoc.unesco.org/ark:/48223/pf0000384655.

Van Wijk-Sijbesma, C. 1998. *Gender in Water Resources Management, Water Supply and Sanitation: Roles and Realities Revisited*. Delft, The Netherlands, International Water and Sanitation Centre (IRC). www.ircwash.org/sites/default/files/Wijk-1998-GenderTP33-text.pdf.

WWAP/UN-Water. 2018. *The United Nations World Water Development Report 2018: Nature-Based Solutions for Water*. Paris, UNESCO. https://unesdoc.unesco.org/ark:/48223/pf0000261424.

Chapter 12

Financing water security and mitigating investment risks

OECD

Lylah Davies and Xavier Leflaive

WWAP

Richard Connor

International human rights law recognizes the responsibility of states to both promote and protect "*the rights to safe and clean drinking water and sanitation as a human right that is essential for the full enjoyment of life and all human rights*" (General Assembly of the United Nations, 2010). In 2022, 2.2 billion people still did not have access to safely managed drinking water services, and 3.5 billion lacked access to safely managed sanitation (UNICEF/WHO, 2023).

Ensuring adequate water and sanitation services for communities and businesses requires making better use of existing sources of finance and mobilizing new ones

Disruptions to freshwater systems, including risks associated with supply availability, extreme climatic events and pollution, have direct implications for well-being, food security, migration, political stability and peace (Gleick and Iceland, 2018). The number of people exposed to floods is expected to grow from the current 1.2 billion to 1.6 billion by 2050 (United Nations, 2019). Already, flooding accounts for some 40% of all losses related to natural catastrophes since 1980, with aggregate losses worldwide totalling more than US$1 trillion (Munich Re, n.d.). In 2021 alone, flooding accounted for US$82 billion in losses (Bevere and Remondi, 2022). At the same time, water scarcity affects 40% of the world population (WHO, n.d.), including 1.2 billion people living in agricultural areas affected by high levels of water stress or high drought frequency (FAO, 2020). Under business as usual, water scarcity alone could cost certain countries across Africa and Asia up to 6% of their gross domestic product (GDP) by 2050 (World Bank, 2016).

Ensuring adequate water and sanitation services (WSS) for communities and businesses requires making better use of existing sources of finance and mobilizing new ones to form a heterogeneous investment landscape for water-related activities. This ranges from river basin- or catchment-scale ecosystem management to storage and flood protection infrastructure, through to the delivery of WSS (Money, 2017). It also requires mainstreaming water security considerations across investments in other sectors. Critically, all solutions to the water crisis will require capital, including significant international financial support for the developing world (OECD, 2022a).

12.1 Investment planning in water resource management

Growing populations and economies, unsustainable management practices and increasing pressures from climate change are straining freshwater resources. The growing gap between water supply and demand leaves entire economies exposed to risks.

Investing across several resource management and service delivery projects, rather than individually, offers several advantages. A strategic planning framework that takes account of exposure and vulnerability to water-related risks, in order to address multiple objectives, can help build system-wide resilience (Brown et al., 2022). Basin-level examples for comprehensive assessments of large-scale water-related infrastructure include analyses of optimal design and operating parameters for a multipurpose dam investment in the Nile River (Jeuland and Whittington, 2014) and the siting, design, and operation of a hydropower plant in the Mekong River, with the view of balancing ecological outcomes (Wild et al., 2018). In the European context, the Water Directive Framework introduces principles of basin-level integrated planning, requiring Member States to develop river basin management plans and programmes of measures to halt the deterioration in the status of water bodies (European Parliament/Council of the European Union, 2000).

Rigorous assessments of the impacts and benefits of investments can create new financing opportunities. Water-related investments, instruments and arrangements can be designed to equitably distribute the costs and benefits across various stakeholders (OECD, 2022b). Valuations can inform policy instruments such as water tariffs, taxes, charges, and permits or offset markets. Similarly, these principles can inform voluntary financing arrangements that link potential returns to an investment, to encourage local actors to provide non-repayable capital for investments that provide operational benefits. For example, water utilities, businesses and property developers can benefit from improved local catchment management that provides higher turnover and lower expenditures for water treatment or improved water quality for their products. There are already examples of these arrangements, including in Mexico, where a brewery invests in the Monterrey Metropolitan Water Fund (see Box 3.1 in United Nations, 2023). In France, the Vittel company provided cash or in-kind payments to encourage farmers to adopt eco-friendly farming practices (Trémolet et al., 2019; OECD, 2020a). Such arrangements also ensure affordable service delivery to recipient groups that do not have the financial means to cover their entire share of the costs.

Mobilizing finance for sustainable water resource management is challenging for several reasons, including weak governance structures and/or low prioritization of water in policy and investment planning. Moreover, many investments are characterized by low risk–return profiles and are local and small-scale in nature (OECD, 2022a).

This points to an important role for public and development partners to help improve enabling conditions for water-related investments, including through strengthening the technical capacity of central and regional authorities to prioritize and plan investments, as well as supporting the development of mechanisms to improve risk–return profiles of investments. It is also important to consider how the use of public funds across other sectors can have negative implications for water resource management, for example where poorly designed subsidy schemes (e.g. for industry, energy or agriculture) create perverse incentives that erode water availability and quality, with wider implications on ecosystem services (OECD, 2022a).

12.2 Optimizing water supply and sanitation investments

Considering the vast investment needs for WSS, particularly in lower- and middle-income countries (LMIC), efforts to increase available capital are a priority. Global costs of achieving Sustainable Development Goal 6 (SDG 6) are estimated to exceed US$1 trillion per year, or 1.21%[54] of global GDP (Strong et al., 2020). This capital can come from several sources, including non-repayable funding from tariffs and domestic tax revenues. Voluntary transfers from external sources, such as international donors are absolutely critical for LMIC. However, existing funding from non-repayable sources does not come close to covering the total investment needs for WSS in many LMIC (Goksu et al., 2017). In 2021, official development assistance (ODA) for WSS was under US$9 billion (OECD.stat, n.d.a).

Based on the *user pays principle*, tariffs should be the largest and most stable source of sector revenues, to be used for operations and maintenance (O&M) expenditures, as well as for expanding infrastructure, upgrading with more efficient or sustainable technologies, or optimizing service provision. At the same time, tariffs have direct implications on access to water services. Where ability-to-pay of water services users is low, tariff revenue is often insufficient for cost recovery on O&M (Goksu et al., 2017). This leaves a large investment gap to be filled by taxes or transfers from external sources. Approaches such as tiered tariffs aim to improve cost recovery whilst also maintaining affordability for low-income users, by providing the lowest rates for consumption, up to a given level, for basic needs. As consumption increases, a higher tariff tier is applied, which incentivizes efficient water use while also supporting cost recovery for water service companies. Tiered tariffs can be progressive when they meet two conditions: (i) the highest tariff blocks are set well above the average cost of service provision and income generated serves to cover the costs of the subsidized lower blocks; and (ii) they take into consideration that poor households can actually consume more water than wealthy ones (because they have larger families, or less water-efficient networks or appliances) (Leflaive and Hjort, 2020). In Chile, a tiered tariff was applied in combination with targeted subsidies to ensure access among marginalized groups of the population (Box 12.1).

---

[54] Based on a 2018 global GDP of US$85.79 trillion.

A disconnect between the accountability and performance of WSS providers can undermine the efficiency of capital expenditures, notably where service providers are highly subsidized public entities, which is often the case in LMIC (OECD, 2022a). This can translate into sub-optimally designed projects, such as oversized WSS infrastructure, which fails to be used to capacity, or that remains unconnected to sewerage networks (Goksu et al., 2017). Inadequate asset management reduces their value and increases the risk that they will need to be replaced prematurely. It also occupies maintenance efforts with fixing asset breakdowns, rather than strategically prioritizing upgrades (ADB, 2014; OECD, 2022a). Due to the monopolistic market structure of water services and the public good dimension of their benefits, regulation has an important role in creating and maintaining incentives for performance (OECD, 2022c; 2022d).

There are often few financial products that channel their investments towards water

Effective governance practices, encompassing both regulatory and institutional dimensions, have a critical role in enabling funds to be used efficiently and effectively, in terms of well-designed and implemented projects, and alignment with broader economic, social and environmental policy objectives (OECD, 2022a; World Bank, 2021). Improving efficiency and governance is a challenging and long-term commitment, requiring engagement across multiple levels of government, the private sector and communities (see Chapter 9). Efforts on behalf of regulators and service providers to increase transparency, accountability and efficiency in spending and operations will be critical to enhance cost recovery, consequently improving the financial stability of service providers and their ability to allocate resources where they are most needed. In addition, these efforts can increase the bankability and creditworthiness of service providers, allowing them to attract greater levels of repayable finance.

12.3 Mobilizing investment for water infrastructure

Large-scale investment is needed to achieve SDG 6, and the private sector has an important role to play. Various types of investments will attract different investors. For example, short-term investments may appeal to commercial financiers, whereas institutional investors are typically interested in larger, longer-term investments, which could include water network extensions with long repayment periods (Goksu et al., 2017).

Yet, water-related investments represent only a minor share of the total stock of institutional investment holdings in infrastructure (an estimated US$17 billion of institutional holdings out of just over US$1 trillion in holdings in 2020 – just 1.7%) (OECD, 2020b). These can include stocks, bonds or real estate that can be held for decades, whereby the annual change in cumulative investment can be relatively low.

While there is increasing interest among private investors, and particularly institutional investors, to grow their sustainable finance portfolios, there are often few financial products that channel their investments towards water (Trémolet et al., 2019). Institutional investors require large investments (often greater than US$10 million) and need to satisfy fiduciary requirements to minimize the risk of losses. Investors and lenders will generally look for stability of revenues and the ability to recover costs and service debt obligations as a measure of financial sustainability and therefore creditworthiness (Money, 2017; OECD, 2019a).

International human rights law recognizes that states have the primary role in, and are obliged to, ensure non-discrimination and equality in the enjoyment of the rights to water and sanitation. States therefore play a large role in providing water supply and sanitation services, and particularly in prioritizing services to marginalized and disadvantaged populations (CESCR, 2003).

In most instances, public and development finance takes the form of direct loans or grants (OECD, 2019b). Development funds can help attract private investment, notably using blended finance approaches that improve the terms for commercial actors through guarantees

Box 12.1 Targeted water supply subsidies (Chile)

In Chile, a tariff for urban water supply and sanitation was implemented under water reforms in the 1980s. These reforms aimed at recovering the costs of service and led to substantial efficiency gains, but also increased the price of supply delivery.

To address concerns over the affordability of services to low-income households, the government introduced an individual means-tested water consumption subsidy in the early 1990s.

The scheme targeted roughly 20% of the poorest households nationwide, for which the water and sanitation services (WSS) bill constituted over 5% of their monthly income. The subsidy covered 25–85% of the cost of households' basic water consumption (up to 15 m^3 a month) and sewerage, with all consumption beyond this limit charged at the full price. The municipality played a central role in the subsidy scheme, receiving applications, determining eligibility and paying the subsidy directly to the water companies from funding received by the central government (OECD/UNECLAC, 2016).

The combined tiered tariff and subsidy scheme enabled Chile to successfully increase water prices to reflect costs without compromising social and distributional goals. By 2000, the cost of the subsidy scheme reached US$42.5 million. This was significantly lower than the cost of the previous universal subsidy scheme, under which water service providers experienced net financial losses. A financial deficit of 2% of assets in the WSS sector became a surplus of 4% leading to net profits of US$107 million – more than double the subsidy scheme's costs (Leflaive and Hjort, 2020).

The subsidy scheme has since been updated and expanded to broaden coverage to vulnerable groups. A 100% subsidy was also introduced for beneficiaries of the welfare programme ('Chile Solidario') designed for very poor households (Contreras et al., 2018).

and grants (OECD, 2018). In 2021, US$ 171 million was mobilized for the water sector with development funds, representing only 1.9% of value of ODA flows to this sector, in the same year (OECD.stat, n.d.b). The strategic use of concessional funds can attract private finance to overcome challenges like the need for long tenors, small ticket sizes, limited creditworthiness and the lack of clearly defined revenue (OECD, 2022a).

Green bonds and special-purpose vehicles (SPVs)[55] that aggregate smaller water-related investments are emerging. Bonds can be a means to raise capital for investments with clearly defined revenue streams, and this can be used to attract institutional investors such as pension funds to projects with long tenors. In Latin America and the Caribbean, for example, few WSS companies have experience in accessing capital markets and the sector only represents 7% of all green bonds issued (Braly Cartillier and Ortega Andrade, 2022). In a pilot in Colombia, the Inter-American Development Bank (IDB) supported two public water and sanitation companies to develop a green bonds framework and identify a combined portfolio of more than 170 eligible projects aligned with the Colombian Green Taxonomy (World Bank, 2022), with an estimated value of US$288 million (Braly Cartillier and Ortega Andrade, 2022).

SPVs allow for the grouping of projects that are too small individually to attract finance under a single legal entity, or for the ownership of large projects under a consortium of project sponsors. An SPV enabled the aggregation of small-scale water utilities in the Veneto region (Italy) to raise US$380 million for capital expenditure, under a single bond that attracted institutional investors.

[55] A special purpose vehicle (SPV) is a subsidiary company that is formed to undertake a specific business purpose or activity.

The bonds were structured and bought by the European Investment Bank (including US$80 million in financing) and other financial institutions (Rees, 2018; EIB, 2022).

Dedicated financing institutions and funds can also support the water sector's access to finance. For example, the Netherlands Water Bank (NWB) issues water bonds, benefiting from its high credit rating, and uses the proceeds to provide financial services to water authorities that would not have obtained finance with the same terms (NWB, n.d.).

A better understanding of water-related risks can make financial actors engage with companies to invest in mitigating those risks

Revolving funds use a mixture of public and private finance to provide loans for water investments and recycle loan repayments into the fund for new investments (OECD, 2022a). This is notably used in the United States of America (USA), as a federal-state partnership, known as the Clean Water State Revolving Fund (CWSRF). The fund is capitalized through federal investment, and then provides low interest loans to eligible recipients for water infrastructure projects. Repayments on loans are recycled back into individual state CWSRF programmes to finance new water infrastructure projects (US EPA, 2023). This type of pooling mechanism can use different sets of instruments, including equity, debt or guarantees to invest in specific sectors or regions. In another example, the Philippine Water Revolving Fund (PWRF) was implemented from 2008 to 2013 by blending concessional finance from the Japan International Cooperation Agency (JICA) and the Development Bank of the Philippines with commercial finance. The programme mobilized US$234 million of loans for WSS, of which 60% came from private banks and developers (DAI, 2014; OECD, 2019b).

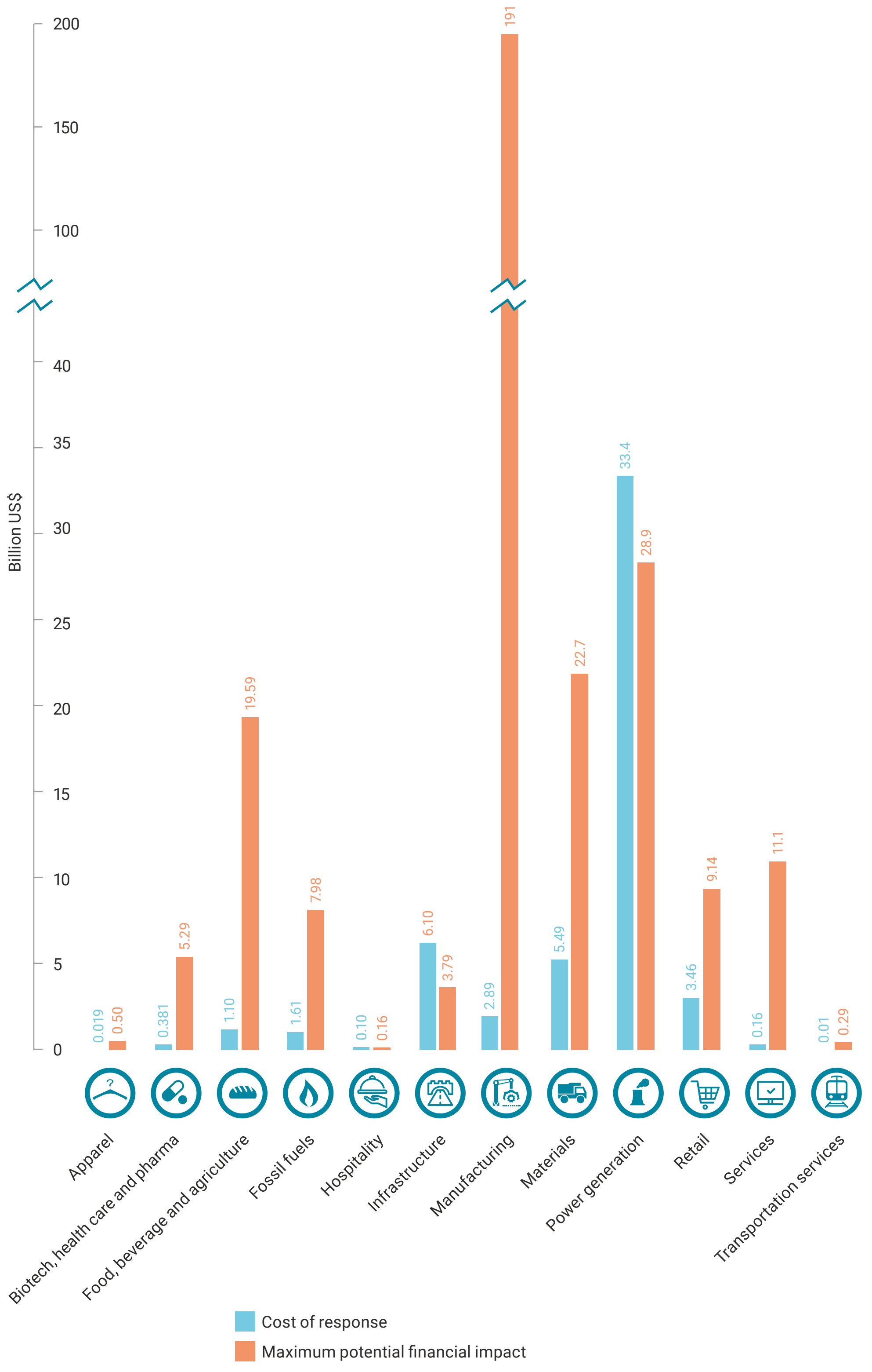
12.4 Reducing investment exposure to water-related risks

The increasing frequency and intensity of extreme climatic and weather events have implications for communities and businesses, with potential macro-economic consequences. Governments are often considered as 'insurers of last resort', expected to compensate for uninsured losses and support reconstruction efforts. This can become unsustainable for budget-constrained governments and increase reliance on non-governmental organizations (NGOs), charities, or the affected households and companies themselves. This points to an important need to understand risks and take actions to reduce exposure or mitigate impacts across the economy.

A better understanding of water-related risks can make financial actors engage with companies to invest in mitigating those risks. In 2020, the cost of water-related risks to businesses was estimated at US$301 billion, while the cost of mitigating these risks would have been US$55 billion (CDP, 2021). The financial impacts of water-related risks exceed the costs of inaction in nearly all sectors (Figure 12.1), with the exception of energy, where large investments are already underway. Asia and Africa show the greatest cost–benefit potential for such investments (Figure 12.2). At the same time, increased understanding of water-related risks can lead to the identification of new commercial opportunities that align with water security objectives. Companies reporting to the 2022 CDP questionnaire estimated US$436 billion in financial opportunities linked to new water-related markets, improved water efficiency in operations, the sale of new products and services, and resilient supply chains (CDP, 2023).

Climate change-resilient infrastructure helps preserve the value of investments and the availability of basic services under conditions of uncertainty (e.g. future demand, resource availability and exposure to environmental risks). It is also a smart financial decision, as protecting assets exposed to hazards in LMIC can provide benefits worth four times their cost (World Bank, 2019). Scenarios can inform current decision-making by exploring impacts on alternative plausible futures, taking into account flood risk management, spatial planning and freshwater supply. This can help to plan shifts beyond designs for robustness, which can tolerate anticipated extremes, towards resilient design, which can also sustain functions under climatic stresses and shocks (OECD, 2022b).

Figure 12.1
Potential financial impact of water risks and the cost of response, 2020*

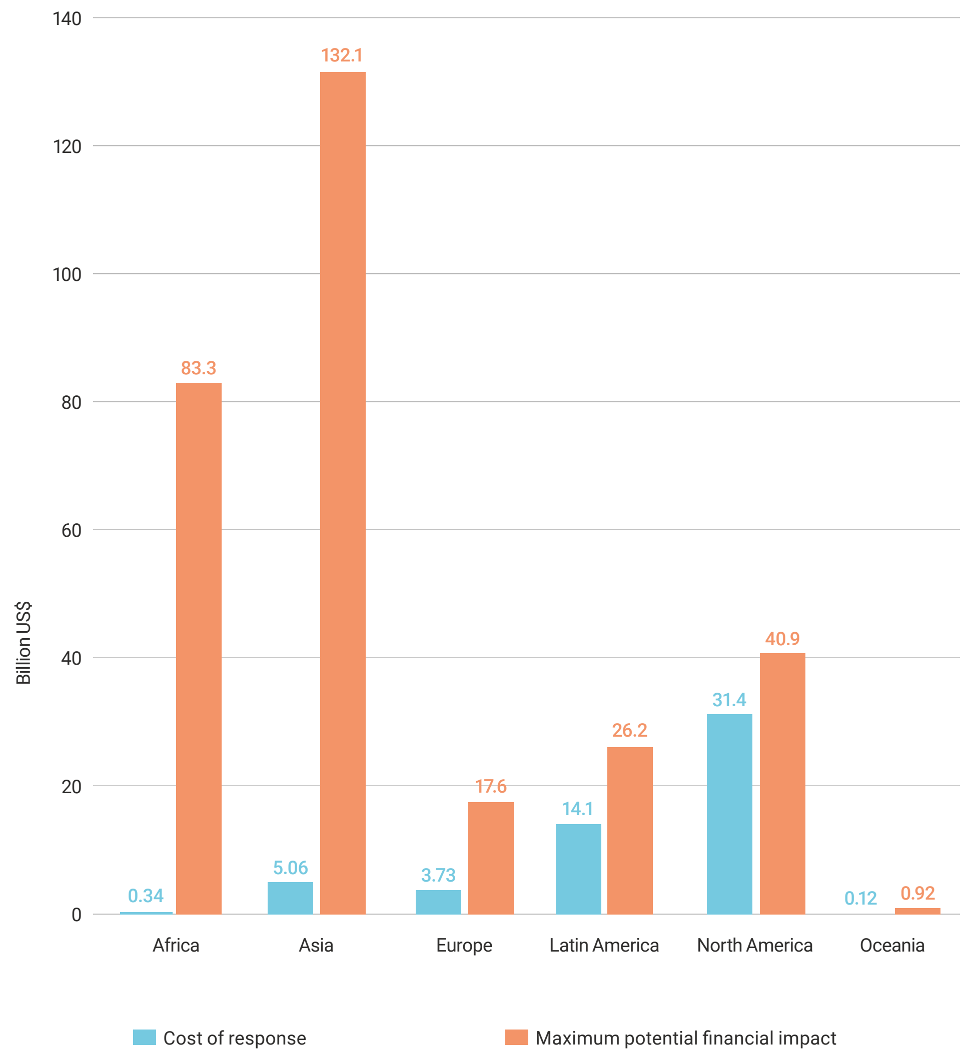


*Based on an analysis of 2,934 companies that reported information about their water risks, impacts and associated responses and strategies.

Source: Adapted from CDP (2021, p. 16).

The private sector and the financial system also play a pivotal role in directing finance towards or away from activities that increase exposure to water-related risks. However, these risks do not seem to be fully understood by central banks. In 2021, only two fifths of surveyed banks had performed a mapping of climate and environment risk exposures. Notably, physical risks did not appear to be priced in the Eurozone banking system (Houben et al., 2021).

Figure 12.2
Potential financial impact of water risk and cost of response per region, 2020*



*Based on an analysis of 2,934 companies that reported information about their water risks, impacts and associated responses and strategies.

Source: Adapted from CDP (2021, p. 14).

Insurance tools mitigate excessive financial losses and can encourage policy holders to reduce exposure. Depending on the country and context, insurance can be managed by private markets, the public sector, or a mixture of both. The United Kingdom of Great Britain and Northern Ireland's Flood Re programme, a joint initiative between the government and insurers, aims to make the flood-related coverage of household insurance more affordable. Insurers can transfer the flood risk element of their insurance policies to Flood Re for a fixed price and be reimbursed by the programme in the advent of flood-related claims. This helps keeps premiums down for the end customer (Flood Re, n.d.). For the agricultural sector, crop insurance and weather index-based insurance can help spread the risk of income loss to farmers after drought or other extreme weather events (OECD, 2022b). This can reduce the need for public compensation or support payments to farmers after extreme events. For example, in India, a number of insurance schemes are implemented to support farmers, including Pradhan Mantri Fasal Bima Yojna, which provides subsidized insurance protection for food crops. Claim payment can be made when sowing is not done due to adverse weather (PMFBY, n.d.).

12.5 Conclusions

Providing sustainable water supply and sanitation services for billions of people around the world remains an urgent task. Water-related events like droughts and floods can have significant implications for food security, migration, political stability and conflict. Ensuring a water-secure future that supports peace and prosperity requires increasing the quantity and quality of water-related investments, particularly for LMIC that are among the most exposed to risks. While this chapter has focused mainly on financing infrastructure, strengthening planning and governance practices are also critical to ensuring that funds are used efficiently. Yet, to meet the scale of investment needed, both public and private sources of finance are needed.

Financing arrangements and vehicles that can support increased investment are increasingly available, notably when de-risked through concessional financing. Several conditions are required for blended finance to materialize at scale (see OECD, 2022a, for a detailed analysis). In this respect, the Organisation for Economic Co-operation and Development (OECD) is developing a scorecard to assess whether enabling conditions are in place at the national level to finance water, with the hope of triggering broader discussions on policy and institutional reforms to accelerate finance for water.

References

ADB (Asian Development Bank). 2014. *Water Utility Asset Management: A Guide for Development Practitioners*. www.adb.org/documents/water-utility-asset-management-guide-development-practitioners.

Bevere, L. and Remondi, F. 2022. *Natural Catastrophes in 2021: The Floodgates are Open*. Swiss Re. www.swissre.com/institute/research/sigma-research/sigma-2022-01.html#:~:text=In%202021%2C%20there%20were%20more,are%20becoming%20ever%20more%20apparent.

Braly Cartillier, I. and Ortega Andrade, A. 2022. Pushing the Limits: How to Expand the Green Bond Market in a Sustainable Way. Interamerican Development Bank (IDB) website, 18 April 2022. blogs.iadb.org/agua/en/green-bonds-water-sanitation/.

Brown, C., Boltz, F. and Dominique, K. 2022. *Strategic Investment Pathways for Resilient Water Systems*. OECD Environment Working Papers No. 202. Paris, OECD Publishing. doi.org/10.1787/9afacd7f-en.

CDP. 2021. *A Wave of Change: The Role of Companies in Building a Water-Secure World*. CDP Global Water Report 2020. London, CDP Worldwide. www.cdp.net/en/research/global-reports/global-water-report-2020.

_____. 2023. *Riding the Wave: How the Private Sector is Seizing Opportunities to Accelerate Progress on Water Security*. Global Water Report 2022. London, CDP Worldwide. www.cdp.net/en/research/global-reports/global-waterreport-2022.

CESCR (Committee on Economic, Social and Cultural Rights). 2003. *General Comment No. 15: The Right to Water (Arts. 11 and 12 of the Covenant)*. Adopted at the twenty-ninth session of the Committee on Economic, Social and Cultural Rights, on 20 January 2003 (Contained in Document E/C.12/2002/11). www.refworld.org/pdfid/4538838d11.pdf.

Contreras, D., Gómez-Lobo, A. and Palma, I. 2018. Revisiting the distributional impacts of water subsidy policy in Chile: A historical analysis from 1998–2015. *Water Policy*, Vol. 20, No. 6, pp. 1208–1226. doi.org/10.2166/wp.2018.073.

DAI. 2014. Philippines—Water Revolving Fund Support Program (PWRF). DAI website. www.dai.com/our-work/projects/philippines-water-revolving-fund-support-program-pwrf. (Accessed on 9 October 2023).

EIB (European Investment Bank). 2022. VIVERACQUA HYDROBOND 4. EIB website. www.eib.org/en/projects/all/20210499.

European Parliament/Council of the European Union. 2000. Water Framework Directive. Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. European Commission. eur-lex.europa.eu/eli/dir/2000/60/oj.

FAO (United Nations Food and Agriculture Organization). 2020. *The State of Food and Agriculture 2020: Overcoming Water Challenges in Agriculture*. Rome, FAO. www.fao.org/3/cb1447en/cb1447en.pdf.

Flood Re. n.d. How Flood Re Works. Flood Re website. www.floodre.co.uk/how-flood-re-works/. (Accessed on 9 October 2023).

General Assembly of the United Nations. 2010. The Human Right to Water and Sanitation. Resolution adopted by the General Assembly on 28 July 2010. Sixty-fourth session. A/RES/64/292. https://digitallibrary.un.org/record/687002.

Gleick, P. and Iceland, C. 2018. *Water, Security and Conflict*. Issue Brief. World Resources Institute (WRI). www.wri.org/research/water-security-and-conflict. (Accessed on 9 October 2023).

Goksu, A., Trémolet, S., Kolker, J. and Kingdom, B. 2017. *Easing the Transition to Commercial Finance for Sustainable Water and Sanitation*. International Bank for Reconstruction and Development/The World Bank. documents.worldbank.org/curated/en/182521503466225465/pdf/119048-WP-REPLACEMENT-PUBLIC.pdf.

Houben, S., Schellekens, G. and Zander, K. 2021. The Clock is Ticking for Banks to Manage Climate and Environmental Risks. European Central Bank (ECB) website, 18 August 2021. www.bankingsupervision.europa.eu/press/publications/newsletter/2021/html/ssm.nl210818_5.en.html.

Jeuland, M. and Whittington, D. 2014. Water resources planning under climate change: Assessing the robustness of real options for the Blue Nile. *Water Resources Research*, Vol. 50, No. 3, pp. 2086–2107. doi.org/10.1002/2013WR013705.

Leflaive, X. and Hjort, M. 2020. *Addressing the Social Consequences of Tariffs for Water Supply and Sanitation*. OECD Environment Working Papers No. 166. Paris, OECD Publishing. doi.org/10.1787/afede7d6-en.

Money, A. 2017. *Scaling-Up Financing through an Attractive Risk-Return Profile*. Background Paper for the 2nd meeting of the Roundtable on Financing Water. OECD. www.oecd.org/environment/resources/RT-Financing-Water-background-paper-session-A-Money-Oxford.pdf.

Munich Re. n.d. Flood Risks on the Rise. Munich Re website. www.munichre.com/en/risks/natural-disasters-losses-are-trending-upwards/floods-and-flash-floods-underestimated-natural-hazards.html. (Accessed on 9 October 2023).

NWB. n.d. NWB Bank: The Sustainable Water Bank. NWB website. nwbbank.com/en (Accessed on 9 October 2023).

OECD (Organisation for Economic Co-operation and Development). 2018. *OECD DAC Blended Finance Principles for Unlocking Commercial Finance for the Sustainable Development Goals*. OECD. www.oecd.org/dac/financing-sustainable-development/blended-finance-principles/guidance-and-principles/.

_____. 2019a. *A Typology of Water-Related Investments*. Background Paper for the 4th meeting of the Roundtable on Financing Water, 26-27 June 2019, Washington, D.C. OECD. www.oecd.org/water/Session1.A-typology-of-water-related-investments.pdf.

_____. 2019b. *Making Blended Finance Work for Water and Sanitation: Unlocking Commercial Finance for SDG 6*. OECD Studies on Water. Paris, OECD Publishing. dx.doi.org/10.1787/5efc8950-en.

_____. 2020a. *Financing Water Supply, Sanitation and Flood Protection: Challenges in EU Member States and Policy Options*. OECD Studies on Water. Paris, OECD Publishing. dx.doi.org/10.1787/6893cdac-en.

_____. 2020b. *Green Infrastructure in the Decade for Delivery: Assessing Institutional Investment, Green Finance and Investment*. Paris, OECD Publishing. dx.doi.org/10.1787/f51f9256-en.

_____. 2022a. *Financing a Water Secure Future*. OECD Studies on Water. Paris, OECD Publishing. doi.org/10.1787/a2ecb261-en.

_____. 2022b. *Water Investment Planning and Financing*. Background Note for the thematic workshop on 15–16 February 2022. OECD. www.oecd.org/water/background-note-water-investment-planningand-financing-15-16-feb-2022.pdf.

_____. 2022c. *Cost Recovery*. Background Note for the thematic workshop on 31 May–1 June 2022. OECD. www.oecd.org/water/background-note-cost-recovery-31-may-1-june-2022.pdf.

_____. 2022d. *Towards Sustainable Water Services in Estonia: Analyses and Action Plan*. OECD Studies on Water. Paris, OECD Publishing. doi.org/10.1787/b82d71c6-en.

OECD/UNECLAC (Organisation for Economic Co-operation and Development/United Nations Economic Commission for Latin America and the Caribbean). 2016. *OECD Environmental Performance Reviews: Chile 2016*. OECD Environmental Performance Reviews. Paris, OECD Publishing. dx.doi.org/10.1787/9789264252615-en.

OECD.stat. n.d.a. Total Flows by Donor (ODA+OOF+Private). OECD.stat website. stats.oecd.org/Index.aspx?DataSetCode=TABLE1. (Accessed on 9 October 2023).

OECD.stat. n.d.b. Mobilisation. OECD.stat website. stats.oecd.org/Index.aspx?DataSetCode=DV_DCD_MOBILISATION. (Accessed on 9 October 2023).

PMFBY (Pradhan Mantri Fasal Bima Yojana). n.d. PMFBY website. pmfby.gov.in/. (Accessed on 9 October 2023).

Rees, M. 2018. *A Sexy Name to Pay for the Pipes*. Part of the series "A Dictionary of Finance". European Investment Bank (EIB) website, 5 March 2018. www.eib.org/en/podcasts/italian-hydrobond#.

Strong, C., Kuzma, S., Vionnet, S. and Reig, P. 2020. *Achieving Abundance: Understanding the Cost of a Sustainable Water Future*. Working Paper. www.wri.org/research/achieving-abundance-understanding-cost-sustainable-water-future.

Trémolet, S., Favero, A., Karres, N., Toledo, M., Kampa, E., Lago, M., Anzaldua, G., Vidaurre, R., Tarpey, J., Makropoulos, C., Lykou, A., Hanania, S., Rebollo, V. and Anton, B. 2019. *Investing in Nature for European Water Security*. London, The Nature Conservancy/Ecologic Institute/ICLEI. www.ecologic.eu/17059. (Accessed on 9 October 2023).

UNICEF/WHO (United Nations Children's Fund/World Health Organization). 2023. *Progress on Household Drinking Water, Sanitation and Hygiene 2000-2022: Special Focus on Gender*. New York, UNICEF/WHO. data.unicef.org/resources/jmp-report-2023/. Licence: CC BY-NC-SA 3.0 IGO.

United Nations. 2019. *Climate Action Pathway: Water*. Executive Summary. Global Climate Action/Marrakech Partnership. https://unfccc.int/sites/default/files/resource/ExecSumm_Water_0.pdf.

_____. 2023. *The United Nations World Water Development Report 2023: Partnerships and Cooperation for Water*. Paris, United Nations Educational, Scientific and Cultural Organization (UNESCO). unesdoc.unesco.org/ark:/48223/pf0000384655?posInSet=1&queryId=524e3791-3f6b-402d-be29-6ª436f0d39bd.

US EPA (United States Environmental Protection Agency). 2023. About the Clean Water State Revolving Fund (CWSRF). EPA website. www.epa.gov/cwsrf/about-clean-water-state-revolving-fund-cwsrf#works.

WHO (World Health Organization). n.d. Drought. WHO website. www.who.int/health-topics/drought#tab=tab_1.

Wild, T. B., Reed, P. M., Loucks, D. P., Mallen-Cooper, M. and Jensen, E. D. 2018. Balancing hydropower development and ecological impacts in the Mekong: Tradeoffs for Sambor Mega Dam. *Journal of Water Resources Planning and Management*, Vol. 145, No. 2. doi.org/10.1061/(ASCE)WR.1943-5452.0001036.

World Bank. 2016. High and Dry: Climate Change Increases Water Risks, Hampers Growth. The World Bank website, 3 May 2016. www.worldbank.org/en/news/video/2016/05/03/high-and-dry-climate-change-increases-water-risks-hampers-growth.

_____. 2019. Lifelines: The Resilient Infrastructure Opportunity. The World Bank website, 17 June 2019. www.worldbank.org/en/news/infographic/2019/06/17/lifelines-the-resilient-infrastructure-opportunity.

_____. 2021. *Infrastructure Governance: Assessment Framework*. International Bank for Reconstruction and Development/The World Bank. thedocs.worldbank.org/en/doc/96550c14d62154355b6edc367d4d7f33-0080012021/original/Infrastructure-Governance-Assessment-Framework-December-2020.pdf.

_____. 2022. Colombia: Leading the Path to Sustainability in Latin America. Feature Story, 7 September 2022. World Bank website. www.worldbank.org/en/news/feature/2022/08/31/colombia-leading-the-path-to-sustainability-in-latin-america.

Chapter 13

Conclusions

WWAP

Richard Connor and Michela Miletto

This report originally sought to demonstrate that developing and maintaining a secure and equitable water future is essential to ensuring prosperity and peace for all. However, as described throughout the previous chapters, the relationship also works in the opposite direction, as poverty (including inequality) and various types or levels of conflict can amplify water insecurity.

The water–prosperity paradox

While water availability has long been recognized as a driver of economic growth, empirical evidence has been difficult to establish. Some countries located in arid and semi-arid areas have well developed economies, whereas other countries with relatively abundant water supplies are amongst the most underdeveloped.

Fully developed water resource infrastructure and management systems can clearly promote growth and prosperity by storing and delivering a reliable water supply to economic sectors, including agriculture, energy, industry, and the relevant business and service sectors that support billions of livelihoods. Similarly, safe, accessible and well-functioning water supply and sanitation systems foster prosperity through quality of life, with individual and community dividends reflected in education and a healthy active workforce.

However, only the richest countries can directly afford building, maintaining and managing such infrastructure, not to mention having all the technical and institutional capacity to do so. This is the water–prosperity paradox: while middle- and lower-income countries require water to develop their economies, they require economic growth in order to finance water. And while affluent neighbourhoods generally receive excellent water supply and sanitation services at a reasonable price, people and households in poorer communities regularly pay much more for an unreliable and often unsafe water supply.

'Economic decoupling' from water use essentially implies increasing water use efficiency (SGD Target 6.4) across all stages of a country's economic development. There is little empirical evidence to support that any observed 'decoupling' over the past decades was the result of specific or intended policy. It seems just as likely (if not more so) a consequence of economic diversification – from water-intensive agriculture and resource extraction towards more lucrative and less water-intensive industries and services. In some cases, water use efficiency gains have been more than cancelled by the expansion of economic activities, resulting in a net increase in water consumption.

Water: agent of peace or instrument of conflict?

The relationship between water and peace/conflict is also complex and equally, if not more, difficult to establish. This report offers several examples where cooperation over water resources has generated positive and peaceful outcomes. These range from participatory, community-led initiatives that have relieved local tensions to the contribution of transboundary water organizations in dispute settlement and peacebuilding in post-conflict settings. It has not been easy to find detailed examples where such efforts have failed, which could have provided equally valuable lessons.

It has often been stated that '*the next wars will be over water*',[56] but there is no conclusive evidence that this has been the case. Water does not yet appear to have become a

---

56 Back in 1995, former World Bank vice-president Ismail Serageldin is reported to have said: "*If the wars of this century were fought over oil, the wars of the next century will be fought over water – unless we change our approach to managing this precious and vital resource.*" https://news.sky.com/story/future-wars-will-there-be-fights-over-water-12713674.

prevalent 'trigger' of conflict. However, as several geopolitical crises unfold worldwide, there have been several reports of attacks targeting civilian water infrastructure, including treatment plants, distribution systems and dams. Such events violate international law and must be severely condemned by the international community.

Global trends: threats and opportunities

Worldwide trends, as well as pivotal events with global implications, can have both direct and indirect effects on prosperity and peace, through water. Water management must therefore be aware of the various factors that can impact socio-economic realities. These factors range from global climatic and geopolitical changes to local social tensions, economic adversity and environmental degradation. They can have profound implications for water, while water-related issues may equally contribute to shaping them.

Global population growth is primarily occurring in urban and peri-urban areas, including informal settlements, with most growth occurring in the less-developed regions of Africa and Asia. ***Urbanization*** and rural-to-urban migration magnify pressure on water and sanitation service providers in cities and municipalities, who struggle to keep up with increasing demand.

Fragile states and ***conflict-affected areas*** are often characterized by unequal access to water and sanitation, arising from breakdown of essential infrastructure, displacement of populations, insecurity and limited access to resources. Water supply, sanitation and hygiene (WASH) can be leveraged as a platform for intercommunal collaboration and partnerships between citizens and government.

Resource scarcity, environmental degradation and unsustainable environmental management practices can prompt ***migration***. Displacement can in turn contribute to water insecurity by increasing the burden on water systems and resources in settlement locations. Cooperation between displaced and host communities promotes peace and understanding, including the identification of mutually beneficial economic prospects.

Disaster risk reduction can address the root causes of vulnerability and build resilience to the impacts of extreme events, including flooding. Mitigation measures include improving access to affordable housing, upgrading infrastructure and services, promoting sustainable land use practices, and adopting nature-based solutions.

Climate change will affect the availability, quality and quantity of water for basic human needs, threatening the effective enjoyment of the human rights to water and sanitation for potentially billions of people. Food security, human health, urban and rural settlements, energy production, industrial development, employment and economic growth, and ecosystems are all water-dependent and thus vulnerable to the impacts of climate change. Climate change ***adaptation*** and ***mitigation*** through water management are therefore critical to nearly all aspects of sustainable development.

The extent of ***ecosystem degradation*** and its role in conflict and losses of prosperity highlight the scope for ecosystem restoration to become a dominant response to many water-related challenges, particularly regarding water quality and availability, resilience and responses to climate change. Ecosystem restoration is now recognized as an urgent and key element for conflict resolution and peacebuilding, as well as a tool to improve access to resources, manage climate-related security risks, reduce recruitment by terrorist groups and alleviate pressure on people to migrate. Opportunities exist to facilitate peace by harnessing the positive role that environmental scientists and educators from both sides can play in conflict resolution.

Beyond hydropower, water plays an important role in all aspects of ***energy production***. The cooling of thermal and nuclear power stations, and the irrigation of biofuels, are particularly water-intensive. In terms of electricity generation, the most water-efficient sources are wind, solar-photovoltaic (PV) and geothermal systems.

Energy storage solutions are required to make up for the intermittent nature of wind and solar power. While pumped-storage hydropower shows much room for expansion, lithium-ion batteries are the fastest-growing storage technology. However, the abstraction of lithium and other critical minerals (for solar panels) is usually highly water-intensive, with significant risks to water quality (especially groundwater), ecosystems and local populations.

Food security can be a key driver of peace and prosperity, but is also highly vulnerable to conflicts disrupting production chains and trade, as well as food distribution. Opportunities to increase water availability for ***agriculture*** include wastewater use, solar-powered irrigation and managed aquifer recharge. Improved water data acquisition and real-time operation and management, combined with technical improvements to existing irrigation systems, can substantially increase crop productivity while lowering water requirements.

An array of ***technologies*** is available to improve both water supply, water use efficiency and the quality and extension of WASH services. These include managed aquifer recharge, desalination, energy-neutral wastewater treatment, water recycling and reuse, climate-smart irrigation, and a variety of water-efficient industrial processes.

However, several rapidly emerging technologies are highly water-intensive and, if left unchecked, could lead to serious problems in the near future. Water consumption by information technology companies has significantly increased in recent years. ***Artificial intelligence*** (AI) and related technologies require large volumes of water for computer cooling systems, in addition to the (often water-intensive) energy required to power the equipment. AI has the potential to enhance basin management, emergency response, and the operation and maintenance of water supply and wastewater treatment plants. The risks associated with AI, and with computerization in general, include system-wide compromise owing to design errors, malfunction and cyber-attacks. ***Carbon capture and storage*** (CCS) systems, which capture CO_2 from greenhouse gas-generating power plants (and other industrial processes such as steel and cement production), are extremely energy- and water-intensive.

Despite advances in remote sensing, metadata analysis and computer modelling, there continues to be a significant lack of historical and up-to-date data and information on surface and groundwater, soil moisture, and associated hydro-meteorological parameters. Government agencies tasked with resource monitoring and management often lack the capacity to collect data and generate information. Some of the most data-sparse regions are also the most vulnerable to hydroclimatic hazards. ***Citizen science*** represents an opportunity for both data collection and public participation in water-related projects.

In many developing countries, water and sanitation are not optimally managed due to a lack of training and relevant skills. The gap in ***skills and capacity*** is even more pronounced on non-technological aspects of water management and governance, such as legal, policy and institutional development. These skills are essential in the context of equitable water governance, especially in complex settings such as transboundary river basins or conflict-prone regions, where resolutions may require a process of negotiation and compromise. Education is the catalyst to uptake and application of such new methods, technologies and behaviours.

There is a growing appreciation for integrating unique ***local and traditional knowledge*** and for directly cooperating with stakeholders, such as farmers and indigenous peoples, in policy, planning and implementation.

Responsible water tenure governance relies on mechanisms and processes that articulate the interests of different actors, mediate their differences, and ensure that their rights and duties are exercised with transparency and equity. Customary arrangements can help secure ***land and water tenure*** of a wide range of individuals and groups. In some countries, however, current water allocation policies exclude indigenous peoples and/or women from establishing and enforcing rights.

The ***collaborative management*** of WASH services and water resources can generate important social capital. Community-based structures to manage water systems (e.g. boreholes, utilities) are common, and they have mostly focused on enhancing the sustainability of WASH infrastructure rather than promoting peace. However, such structures can become a peacebuilding asset if they are equipped and supported to perform that role.

Equitable water allocation encourages investment and benefit-sharing, and ultimately promotes social cohesion. However, the complexities of water management – the range of issues, actors and jurisdictions – extends beyond the basin and across sectors. A central role of water governance is addressing competition and resolving disputes over water, taking into account the policies that undermine the needs of the agricultural, energy, health and industrial sectors, as well as the informal sector in those cases where it plays a significant role (e.g. water vending).

All solutions to the water crisis will require ***financing,*** including significant international support for the developing world. Ensuring adequate water and sanitation services for communities and businesses requires making better use of existing sources of finance and mobilizing new ones. Mobilizing finance can be undermined by weak governance structures and/or low prioritization of water in policy and investment planning.

Investing across several resource management and service delivery projects, rather than individually, offers several advantages, including a more comprehensive understanding of shared benefits. The use of public funds across other sectors can have negative implications for water resource management, for example where poorly designed subsidy schemes create perverse incentives that erode water availability and quality, with wider implications on ecosystem services and local communities.

Shared water can be an important source of cooperation, and shared investments lead to shared benefits. ***Transboundary*** river basin organizations can act as connectors and active peacemakers by strengthening regional integration, facilitating inclusive dialogue and promoting participatory decision-making. While cooperation over shared surface water appears to be gaining momentum, groundwater resources remain grossly neglected, with only a handful of aquifer-specific transboundary agreements.

Coda

Sustainable water management generates a plethora of benefits to individuals and communities, including health, food and energy security, protection from natural disasters, education, improved living standards and employment, economic development, and a variety of ecosystem services.

It is through these benefits that water leads to prosperity.

And equitable sharing of these benefits promotes peace.

When it comes to water, sharing truly is caring.

The choice is ours.

Abbreviations and acronyms

ADB	Asian Development Bank
AI	Artificial intelligence
AMCOW	African Ministers' Council on Water
BCR	Benefit–cost ratio
CCS	Carbon capture and storage
CDP	formerly the Carbon Disclosure Project
CFS	Committee on World Food Security
CIP	Cleaning in place
COVID-19	Coronavirus disease 2019
CSP	Concentrated solar power
CWSRF	Clean Water State Revolving Fund
DIKTAS	Dinaric Karst Aquifer System
EIP	Eco-industrial park
ESCAP	Economic and Social Commission for Asia and the Pacific
FAO	Food and Agricultural Organization of the United Nations
FASRB	Framework Agreement on the Sava River Basin
GDP	Gross domestic product
GHG	Greenhouse gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (German Agency for International Cooperation)
GRID	Global Report on Internal Displacement
GWP	Global Water Partnership
IBRD	International Bank for Reconstruction and Development
ICWC	Interstate Commission for Water Coordination of Central Asia
IDA	International Development Association
IDMC	Internal Displacement Monitoring Centre
IEA	International Energy Agency
IFAD	International Fund for Agricultural Development
IFAS	International Fund for Saving the Aral Sea
IFI	International Financial Institution
IGRAC	International Groundwater Resources Assessment Centre
IHE	Institute for Water Education
IHP	Intergovernmental Hydrological Programme
IOM	International Organization for Migration
IoT	Internet of Things
IPBES	Intergovernmental Science–Policy Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
IPLCs	Indigenous peoples and local communities
IRMA	Initiative for Responsible Mining Assurance
IUCN	International Union for Conservation of Nature
IWMI	International Water Management Institute
IWRM	Integrated water resources management
KnoWat	Knowing Water Better project
LCBC	Lake Chad Basin Commission
LMIC	Lower- and middle-income countries
MRC	Mekong River Commission
NbS	Nature-based solution
NENA	Near East and North Africa
NGO	Non-governmental organization
NIC	National Inter-Ministerial Committee
NRMPBC	Natural Resource Management and Peacebuilding Committee
NWSAS	North-Western Sahara Aquifer System
ODA	Official development assistance
OECD	Organisation for Economic Co-operation and Development

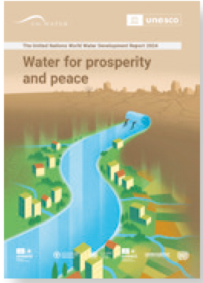
OHCHR	Office of the High Commissioner for Human Rights
O&M	Operations and maintenance
OMVS	Organisation pour la mise en valeur du fleuve Sénégal (Senegal River Basin Development Organization)
OSU	Oregon State University
PPP	Public–private partnership
PSH	Pumped-storage hydropower
PV	Photovoltaic
R&D	Research & Development
SADC	Southern Africa Development Committee
SDG	Sustainable Development Goal
SPP	Salween Peace Park
SPV	Special-purpose vehicle
TDA	Transboundary diagnostic analysis
TNC	The Nature Conservancy
UK	United Kingdom of Great Britain and Northern Ireland
UN	United Nations
UNCCD	United Nations Convention to Combat Desertification
UNDESA	United Nations Department of Economic and Social Affairs
UNDP	United Nations Development Programme
UNECA	United Nations Economic Commission for Africa
UNECE	United Nations Economic Commission for Europe
UNECLAC	United Nations Economic Commission for Latin America and the Caribbean
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNESCWA	United Nations Economic and Social Commission for Western Asia
UNICEF	United Nations Children's Fund
UNIDO	United Nations Industrial Development Organization
UNU	United Nations University
UNU-CRIS	UNU Institute on Comparative Regional Integration Studies
UNU-EHS	UNU Institute for Environment and Human Security
UNU-MERIT	UNU Maastricht Economic and Social Research Institute on Innovation and Technology
USA	United States of America
UN WWDR	United Nations World Water Development Report
WaPOR	Water Productivity Remote Sensing Portal
WASH	Water, sanitation and hygiene
WEF	World Economic Forum
WFP	World Food Programme
WHO	World Health Organization
WMO	World Meteorological Organization
WSS	Water and sanitation services
WUA	Water user association
WWAP	World Water Assessment Programme

THE UNITED NATIONS WORLD WATER DEVELOPMENT REPORT

ISBN 978-92-3-100576-3

212 pages
Price: EUR 55.00

UN WWDR 2023 Full colour, with boxes, figures, maps, tables, notes, photographs, references, and list of abbreviations and acronyms, as well as Forewords by the United Nations Secretary-General António Guterres, UNESCO Director-General Audrey Azoulay and UN-Water Chair and ILO Director-General Gilbert F. Houngbo



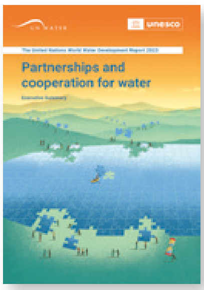
ISBN 978-92-3-100657-9

176 pages
Price: EUR 55.00

UN WWDR 2024 Full colour, with boxes, figures, maps, tables, notes, photographs, references, and list of abbreviations and acronyms, as well as Forewords by UNESCO Director-General Audrey Azoulay and UN-Water Chair and IFAD President Alvaro Lario

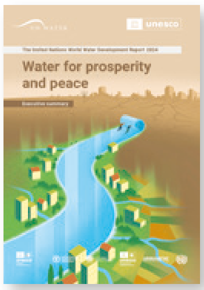
To download the PDF format of the report and associated publications, WWDR previous editions and media material, please visit: https://www.unesco.org/en/wwap.

ASSOCIATED PUBLICATIONS

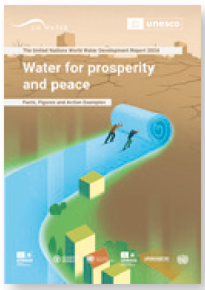


Executive Summary of
the UN WWDR 2023
12 pages
Available in Arabic, Chinese, English, French, German, Hindi, Italian, Korean, Mongolian, Portuguese, Russian and Spanish

Facts, Figures and
Action Examples from
the UN WWDR 2023
16 pages
Available in English, French, Italian, Portuguese and Spanish



Executive Summary of
the UN WWDR 2024
12 pages
Available in Arabic, Chinese, English, French, German, Hindi, Italian, Korean, Portuguese, Russian and Spanish



Facts, Figures and
Action Examples from
the UN WWDR 2024
20 pages
Available in English, French, Italian, Portuguese and Spanish

To download these documents, please visit: https://en.unesco.org/wwap.

unesco
World Water
Assessment Programme

UN-WATER REPORTS AND OTHER RELEVANT PUBLICATIONS

UN-Water coordinates the efforts of United Nations entities and international organizations working on water and sanitation issues. By doing so, UN-Water seeks to increase the effectiveness of the support provided to Member States in their efforts towards achieving international agreements on water and sanitation. UN-Water publications draw on the experience and expertise of UN-Water's Members and Partners.

United Nations World Water Development Report
The United Nations World Water Development Report is UN-Water's flagship report on water and sanitation issues, focusing on a different theme each year. The report is published by UNESCO on behalf of UN-Water, and its production is coordinated by the UNESCO World Water Assessment Programme. The report gives insight on main trends concerning the state, use and management of freshwater and sanitation, based on work done by the Members and Partners of UN-Water. Launched in conjunction with World Water Day, the report provides decision-makers with knowledge and tools to formulate and implement sustainable water policies. It also offers best practices and in-depth analyses to stimulate ideas and actions for better stewardship in the water sector and beyond.

Blueprint for Acceleration: Sustainable Development Goal 6 Synthesis Report on Water and Sanitation 2023
The SDG 6 Synthesis Report on Water and Sanitation 2023 provides a strategic response to the outcomes of the UN 2023 Water Conference. As a "blueprint" it is a concise guide to accelerate progress on water and sanitation, including the implementation of Water Action Agenda commitments. The report, written by the UN-Water family of Members and Partners, is a concise guide to delivering concrete results – offering actionable policy recommendations directed towards senior decision-makers in Member States, other stakeholders, and the United Nations system to get the world on track to achieve SDG 6 by 2030. It was released ahead of the discussions of Member States and relevant stakeholders at the 2023 High-level Political Forum on Sustainable Development, which included a Special Event focused on SDG 6 and the Water Action Agenda.

United Nations system-wide strategy for water and sanitation
In response to the UN 2023 Water Conference and building on the SDG 6 Global Acceleration Framework, UN-Water Members decided to support the development of a United Nations system-wide strategy for water and sanitation. Subsequently, General Assembly resolution A/RES/77/334 "requests the Secretary-General to present a United Nations system-wide water and sanitation strategy in consultation with Member States before the end of the seventy-eighth session of the General Assembly." The goal of the strategy is to enhance UN system-wide coordination and delivery of water-related priorities resulting in more strategic, effective, coherent, and efficient support to Member States in their efforts to accelerate progress on national plans and priorities, internationally agreed water-related goals and targets, and transformative solutions to current and future water-related challenges. The strategy will be launched in July 2024.

SDG 6 Progress Update – 8 reports, by SDG 6 global indicator
This series of reports provides an in-depth update and analysis of progress towards the different SDG 6 targets and identifies priority areas for acceleration: *Progress on household drinking water, sanitation and hygiene* (WHO and UNICEF, as part of the JMP reports), *Progress on wastewater treatment* (WHO and UN-Habitat), *Progress on ambient water quality* (UNEP), *Progress on water-use efficiency* (FAO), *Progress on level of water stress* (FAO), *Progress on integrated water resources management* (UNEP), *Progress on transboundary water cooperation* (UNECE and UNESCO), *Progress on water-related ecosystems* (UNEP) and *Progress on international cooperation and local participation* (WHO, as part of the GLAAS reports). The reports, produced by the responsible custodian agencies, present the latest available country, region and global data on the SDG 6 global indicators, and are published every two to three years. The next updates will be published in July/August 2024.

UN-Water Global Analysis and Assessment of Sanitation and Drinking-Water (GLAAS)
The GLAAS report is produced by WHO on behalf of UN-Water. It provides a global update on the policy frameworks, institutional arrangements, human resource base, and international and national finance streams in support of water and sanitation. It is a substantive input into the activities of Sanitation and Water for All as well as the progress reporting on SDG 6. The next report will be published in 2025.

Progress reports of the WHO/UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene (JMP)
The JMP is affiliated with UN-Water and is responsible for global monitoring of progress towards SDG 6 targets for universal access to safe and affordable drinking-water and adequate and equitable sanitation and hygiene services. Every 2 years, the JMP releases updated estimates and progress reports for WASH in households (as part of the progress reporting on SDG 6, see above), schools and health care facilities.

UN-Water Country Acceleration Case Studies
To accelerate the achievement of SDG 6 targets as part of the SDG 6 Global Acceleration Framework, UN-Water releases SDG 6 Country Acceleration Case Studies to explore countries' pathways to achieving accelerated progress on SDG 6 at the national level. The case studies document replicable good practices for achieving the SDG 6 targets as well as look at how progress can be accelerated across SDG 6 targets in a country. Since 2022, six case studies have been released from Costa Rica, Pakistan, Senegal, Brazil, Ghana and Singapore. Three new ones are planned to be released in July 2024 from Cambodia, Czechia and Jordan.

Policy and Analytical Briefs
UN-Water's Policy Briefs provide short and informative policy guidance on the most pressing freshwater-related issues that draw upon the combined expertise of the United Nations system. Analytical Briefs provide an analysis of emerging issues and may serve as basis for further research, discussion and future policy guidance.

UN-WATER PLANNED PUBLICATIONS

- UN-Water Policy Brief on Transboundary Waters Cooperation – update

More information: www.unwater.org/unwater-publications/

WORLD WATER DAY AND THE UNITED NATIONS WORLD WATER DEVELOPMENT REPORT

The United Nations designates specific days, weeks, years and decades as occasions to mark particular events or topics in order to promote, through awareness and action, the objectives of the Organization.

International observances are occasions to educate the general public on issues of concern, to mobilize political will and resources to address global problems, and to celebrate and reinforce achievements of humanity.

The majority of observances have been established by resolutions of the United Nations General Assembly. World Water Day (22 March) dates back to the 1992 United Nations Conference on Environment and Development where an international observance for water was recommended.

The United Nations General Assembly responded by designating 22 March 1993 as the first World Water Day. It has been held annually since then and is one of the most popular international days together with International Women's Day (8 March), the International Day of Peace (21 September) and Human Rights Day (10 December).

Every year, UN-Water — the UN's coordination mechanism on water and sanitation — sets a theme for World Water Day corresponding to a current or future water-related challenge. This theme also inspires the theme of the United Nations World Water Development Report that is presented on World Water Day. The publication is UN-Water's flagship report and provides decision-makers with tools to formulate and implement sustainable water policies. The report also gives insight on main trends including the state, use and management of freshwater and sanitation, based on work by the Members and Partners in UN-Water.

The report is published by UNESCO, on behalf of UN-Water, and its production is coordinated by the UNESCO World Water Assessment Programme.

Water nurtures prosperity by meeting basic human needs, supporting health and livelihoods and economic development, underpinning food and energy security, and defending environmental integrity.

The impacts of climate change, geopolitical unrest, pandemics, mass migration, hyperinflation and other crises can exacerbate water access inequalities. In nearly all cases, the poorest and most vulnerable groups are those that suffer the greatest risks to their well-being and livelihoods.

The ***2024 edition*** of the ***United Nations World Water Development Report (UN WWDR)*** describes how developing and maintaining a secure and equitable water future underpins ***prosperity and peace*** for all. It calls attention to the complex and interlinked relationships between water, prosperity and peace, describing how progress in one dimension can have positive, often essential, repercussions on the others.

Water infrastructure promotes growth and prosperity by storing a reliable water supply and delivering it to economic sectors, including agriculture, industry, energy and the relevant business and service sectors that support billions of livelihoods. Similarly, safe, accessible and well-functioning drinking water and sanitation systems foster prosperity through quality of life, greater education opportunities and a healthy workforce.

Cooperation over water resources has generated positive and peaceful outcomes, ranging from participatory, community-led initiatives that have relieved local tensions, to dispute settlement and peacebuilding in post-conflict settings and transboundary watersheds. However, inequalities in the allocation of water resources, in access to water supply and sanitation services, and in the distribution of social, economic and environmental benefits can be counterproductive to peace and social stability.

The UN WWDR is UN-Water's flagship report on water and sanitation issues, focusing on a different theme each year. The report is published by UNESCO, on behalf of UN-Water and its production is coordinated by the UNESCO World Water Assessment Programme. The report gives insight on main trends concerning the state, use and management of freshwater and sanitation, based on work done by Members and Partners of UN-Water. Launched in conjunction with World Water Day, the report provides decision-makers with knowledge and tools to formulate and implement sustainable water policies. It also offers best practices and in-depth analyses to stimulate ideas and actions for better stewardship in the water sector and beyond.

This publication is financed by
the Government of Italy and Regione Umbria.

REPVBBLICA ITALIANA

Regione Umbria

9 789231 006579