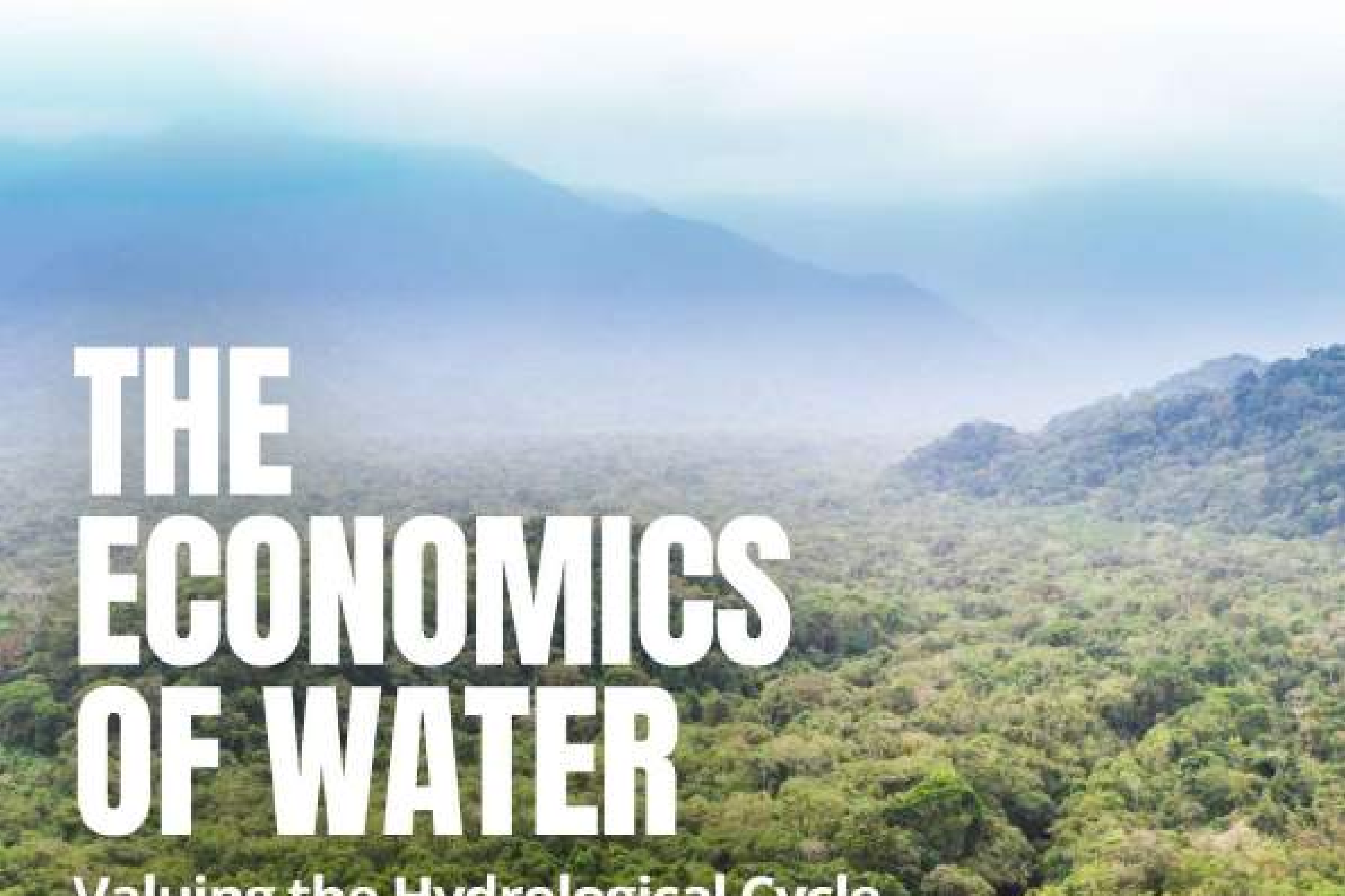
GLOBAL COMMISSION on the ECONOMICS OF WATER



THE ECONOMICS OF WATER

Valuing the Hydrological Cycle as a Global Common Good

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Preface by the Co-Chairs

We need a sea change in how we understand and act on water. The purpose is clear: bring back stability to the global water cycle, deliver on the human right to safe water, achieve food security and development that works for all, and keep our planet safe for generations to come.

The global crisis of water hurts the most vulnerable first, and hardest. More than 1,000 children under five die every day from unsafe water and lack of sanitation. Yet no community or economy will be spared the consequences of a water cycle that is out of kilter - itself the result of our collective actions over decades. Most dangerously, we will fail on climate change if we fail on water. We will also fail on each and every one of the Sustainable Development Goals.

As Co-Chairs of the Global Commission on the Economics of Water, we are convinced that the world can turn the tide on this crisis. But only if we acknowledge why existing approaches have failed, embrace a fresh policy lens, and move with the boldness and urgency that the crisis demands.

The Commission's report sets out the shifts required to drive radical changes in how water is valued, managed, and used. The new economics of water begins by recognising that the water cycle must now be governed as a global common good, that can only be fixed collectively, through concerted action in every country, collaboration across boundaries and cultures, and for benefits that will be felt everywhere.

Critically, we must value water properly to reflect the multiple benefits it provides as Earth's most precious resource, including the roles of green water – the water stored as soil moisture and in vegetation - in sequestering carbon and sustaining nature's ecosystems. We must ensure that prices, subsidies, and other incentives are brought together to ensure that water is used more efficiently in every sector, more equitably in every population, and more sustainably. We must shape economies to allocate and use water properly from the start and avoid having to fix problems after they occur. And we must organise all stakeholders, from local to global, around the missions that get to the heart of the global water crisis, so as to spur a wave of innovations, capacity-building and investments - and evaluate them not in terms of short-run costs and benefits but for how they can catalyse long-run, economy-wide benefits.

Our report, The Economics of Water: Valuing the Hydrological Cycle as a Global Common Good, is inspired by, and builds on, the game-changing Stern Review on the Economics of Climate Change and Dasgupta Review on the Economics of Biodiversity. We hope that the trilogy provides a pathway for integrated thinking and action on these fundamentally interrelated challenges of sustainability.

The Commission submits this report to help advance new thinking and actions under the multilateral water agenda, including the important work of the UN Special Envoy for Water and that being pursued under the UN System-wide Strategy for Water and Sanitation, and the initiatives leading to the UN Water Conference 2026. We also call for water's critical role, and the need for collective action to restore a stable hydrological cycle, to be recognised in deliberations under the UN Framework Convention on Climate Change (UNFCCC), Convention to Combat Desertification (UNCCD) and Convention on Biological Diversity (CBD).

As Co-Chairs, we are grateful to our colleagues on the Commission, whose wisdom and diverse experiences were integral to our work. We also benefitted greatly from insights from experts from across the public and private sectors, academia, and civil society. We also thank the Government of the Netherlands as the convener of our Commission, for having entrusted us with this vital task, and the OECD for their invaluable support.

The Commission's recommendations are only the beginning of a new journey. It must be a journey that involves continuous dialogue, and that makes inclusivity an action, not just a goal. One that involves all voices including youth, women, marginalised communities, and the Indigenous Peoples on the frontlines of water conservation. One that catalyses a new understanding among leaders and mayors, civil society activists and social scientists, and that motivates businesses to do well by contributing to the public good. A journey that ultimately creates a new social contract: to achieve justice and dignity everywhere and sustains the benefits of nature's ecosystems for humanity.

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President, Republic of Singapore

Mariana Mazzucato

Professor in the Economics of Innovation and Public Value at University College London and Founding Director of the UCL Institute for Innovation and Public Purpose

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Henk Ovink

Executive Director, Commissioner, Global Commission on the Economics of Water

"Creating the Global Commission on the Economics of Water, we aimed to bring together leaders across generations, expertise and cultures, beyond water. I am convinced that the watercycle needs to be understood and valued by everyone. Working together and fostering our collective perspectives, we were able to capture the true values of both green and blue water and imagine just water partnerships. We want to inspire and provoke, because we must reshape our shared relationship with water for sustainable, impactful and just transitions."

Henk Ovink

Preface by youth

A tilted hydrological cycle is fundamentally an intergenerational issue. Since its launch at the World Water Forum in Bali, the Youth Water Agenda has engaged with hundreds of young people worldwide who recognise the stakes and are committed to protecting our global common good. However, current market and societal structures significantly limit young people's ability to fully participate in properly valuing and governing of the hydrological cycle as a global common good.

The continued overexploitation and mismanagement of water by current generations are pushing the hydrological cycle increasingly out of balance, amplifying global instability. This has obstructed our ability to tackle the climate and biodiversity crises, meaning that both current and future generations are already facing and will continue to face even harsher periods of water scarcity and floodings, leading to increased economic hardship, social conflict, and environmental degradation. We, the youth and generations to come, will most acutely experience the consequences of today's inaction, and we have the right to meaningfully participate in shaping the world we will inherit.

As young people, we must (1) ensure that blue and green water resources are used sustainably and replenished so that future generations inherit a system capable of supporting their needs; (2) commit to protecting the balance of the hydrological cycle so that both present and future generations have equitable access to clean and sufficient water, including for productive use, and prevent the concentration of resources or pollution in ways that would disadvantage those to come; and (3) hold to account the current generation to act as stewards of our global common good, taking responsibility for the long-term impacts of their decisions on water, ecosystems and beyond.

A key mission of the Youth Water Agenda is to secure dignified livelihoods for current and future generations in a world where uncertainty is rapidly becoming the norm. We believe that true intergenerational justice can only be achieved if young people are meaningful engaged and systematically included within decision-making processes across governing institutions, multilateral systems and frameworks.

Strong investments in transforming educational systems are imperative to ensure we have a generation well-prepared to safeguard the hydrological cycle. Young engineers, economists, farmers, entrepreneurs, researchers, bankers and policymakers are uniquely positioned to foster a systemic understanding of water-related challenges and spark transformational shifts. The youth potential is immense, yet, many areas of value creation within our societies – including academia, industry, and policymaking – remain hierarchical and dominated by older generations. Therefore, we urge governments at all levels to invest in youth and shape today's labour markets to integrate young professionals and their voices into the economy. By investing in education and creating green jobs for young professionals, we can unlock exponential growth in intergenerational innovation and research across sectors, address systemic challenges and drive change, while scaling up and supporting existing youth-led solutions and talent.

In building a safe and just water future, as endorsed by the Global Commission on the Economics of Water, young people must be continuously included, consulted and adequately compensated at each step of the process, with robust accountability mechanisms, to promote an intergenerational approach to water governance. Shaping markets means investing in youth today - a condition for success tomorrow.

Elizabeth Wathuti, on behalf of the Youth Expert Group

Founder, Green Generation Initiative, Commissioner, Global Commission on the Economics of Water

Executive summary

From crisis to opportunity

The world faces a growing water disaster. For the first time in human history, the hydrological cycle is out of balance, undermining an equitable and sustainable future for all.

We can fix this crisis if we act more collectively, and with greater urgency. Vitally too, restoring stability of the water cycle is critical not only in its own right, but to avoid failing on climate change and safeguarding all the earth's ecosystems, as well as on each and every one of the Sustainable Development Goals (SDGs). It will preserve food security, keep economies and job opportunities growing, and ensure a just and liveable future for everyone.

Decades of collective mismanagement and undervaluation of water around the world have damaged our freshwater and land ecosystems and allowed for the continuing contamination of water resources. We can no longer count on freshwater availability for our collective future. More than 1,000 children under five die every day from illnesses caused by unsafe water and sanitation. Women and girls spend 200 million hours each day collecting and hauling water. Food systems are running out of fresh water, and cities are sinking as the aquifers underneath them run dry.

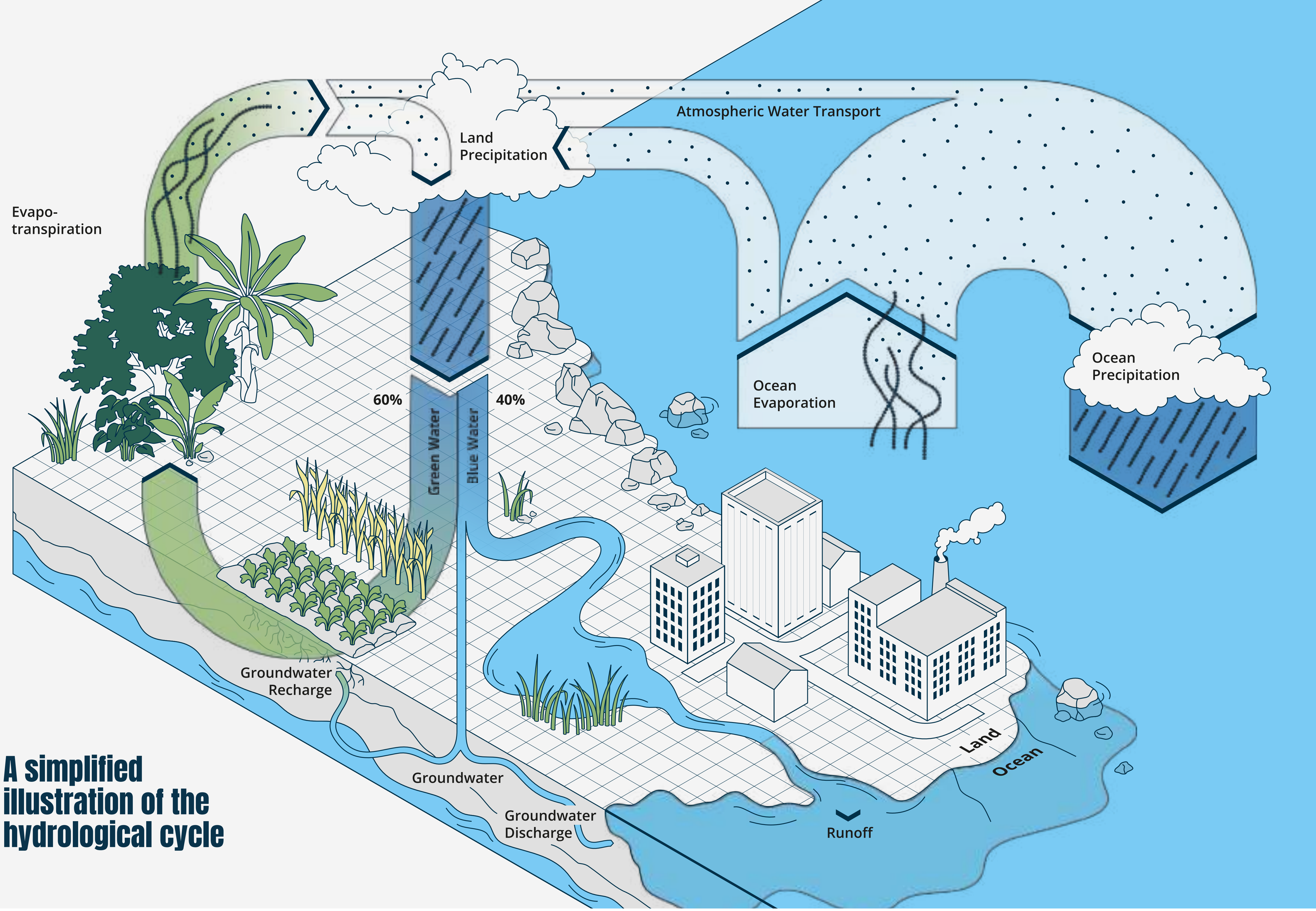
We have, fundamentally, put the hydrological cycle itself under unprecedented stress, with growing consequences for communities and countries everywhere. Our policies, and the science and economics that underpin them, have also overlooked a critical freshwater resource, the "green water" in our soils and plant life, which ultimately circulates through the atmosphere and generates around half the rainfall we receive on land.

Most gravely, while itself a victim of climate change, the degradation of freshwater ecosystems including the loss of moisture in the soil has become a driver of climate change and biodiversity loss. The result is more frequent and increasingly severe droughts, floods, heatwaves, and wildfires, playing out across the globe. And a future of growing water scarcity, with grave consequences for human security. Nearly 3 billion people and more than half of the world's food production are now in areas where total water storage is projected to decline.

We need bolder and more integrated thinking and a recasting of policy frameworks to address these challenges. The Global Commission on the Economics of Water (GCEW) calls for a new economics of water:

- One that recognises the hydrological cycle as a global common good: understanding that it connects countries and regions through both the water that we see and atmospheric moisture flows; that it is deeply interconnected with climate change and the loss of biodiversity with each rebounding on the other; and that it impacts on virtually all the SDGs.

- One that transforms water governance at every scale, from local to river basin to global, to ensure it is governed more effectively and efficiently, delivers access and justice for all, and sustains the earth's ecosystems.
- One that brings together fundamental economic concepts and tools, to value water properly to reflect its scarcity and the multiple benefits it provides as the Earth's most precious resource.
- One that tackles externalities caused by the misuse and pollution of water but shifts from fixing them after the fact to shaping economies so that water is used efficiently, equitably, and sustainably from the start.
- One that spurs a wave of innovations, capacity-building and investments, evaluating them not in terms of short-run costs and benefits but for how they can catalyse long-run, economy wide benefits and hence dynamic efficiency gains through learning, scale economies and cost reductions.
- One that recognises that the costs entailed in these actions are very small in comparison to the harm that continued inaction will inflict on economies and humanity.



A simplified illustration of the hydrological cycle

Why we must govern the water cycle as a global common good

It starts with recognising that the problems we face are not only local. Communities, countries and regions are interdependent not just through transboundary blue water – as globally, more than 263 watersheds and 300 aquifers span political boundaries - but through atmospheric moisture flows that travel great distances.

Current approaches tend to focus on water resources rather than the economic drivers that shape the water cycle. They also deal predominantly with the water we can see – the "blue water" in our rivers, lakes, and aquifers. They overlook a critical freshwater resource, namely "green water" – the water stored as soil moisture and in vegetation, which returns to the air through evaporation and transpiration. As it circulates naturally, green water generates around half of all rainfall over land, the very source of all our freshwater.

Further, current approaches too often assume stable patterns of water supply year after year, but this is no longer true: as land-use changes and global warming destabilise the water cycle, rainfall patterns are shifting.

Most dangerously, disruptions to the water cycle are deeply intertwined with climate change and the depletion of the world's biodiversity, with each reinforcing the other. A stable supply of green water in soils is crucial to sustaining the natural systems that absorb more than a quarter of the carbon dioxide emitted from fossil-fuel combustion.

Yet the loss of wetlands and soil moisture, together with deforestation, is depleting the planet's greatest carbon stores, accelerating global warming.

In turn, rising temperatures trigger extreme heatwaves and increased moisture loss, severely drying landscapes and heightening the risk of wildfires. When viewed holistically, the impact of water scarcity on both people and nature now jeopardises virtually every one of the SDGs. Left unchecked, it will result in growing gaps in nutrition in populations already at risk, the greater spread of diseases, widening inequalities within and across nations, and increased conflicts and forced migration.

The water cycle must therefore be governed as a global common good: recognising, first, our interdependence through both blue and green water flows; second, the wicked interaction between the water crisis, climate change, and the loss of the planet's natural capital; and third, how water flows through all our 17 SDGs. A destabilised water cycle is a large-scale collective and systemic problem, which can only be fixed through concerted action in every country and collaboration across boundaries and cultures.

A shared understanding of the common good is crucial. Otherwise, what might look good for one country today could easily create problems for that same country tomorrow, as well as for others around the world.

The costs of inaction

The human and economic costs of inaction will be substantial. Globally, total water stored on and beneath the Earth's surface is unstable and declining across areas where populations and economic activity are concentrated, and crops are grown.

- High-population density hotspots, including northwestern India, northeastern China and south and eastern Europe, are particularly vulnerable.
- The poorest 10% of the global population obtain over 70% of their annual precipitation from land-based sources and will be hardest hit by deforestation.
- If rainfall that originates from deforestation hotspots were to disappear, growth rates in Africa and South America could drop significantly – by 0.5 and 0.7 percentage points, respectively.
- Intensely irrigated regions tend to see declines in water storage with some experiencing a rate of decline twice as fast as other regions. If current trends persist, extreme water storage declines could make irrigation unfeasible, leading to a 23% reduction in global cereal production.

The economic impacts of such trends will be severe. The combined effects of changing precipitation patterns and rising temperatures due to climate change, together with declining total water storage and lack of access to clean water and sanitation imply that high-income countries could see their GDPs shrink by 8% by 2050 on average, while lower-income countries could face even steeper declines of between 10% and 15%. Disruptions of the hydrological cycle therefore have major global economic impacts.

The water challenge becomes even more pressing when we recognise how much water each person needs daily to live a dignified life. While 50 to 100 litres per day is required to meet essential health and hygiene needs, a dignified life – including adequate nutrition and consumption – requires a minimum of about 4,000 litres per person per day. Most regions cannot secure this much water locally. Although trade could help distribute water resources more equitably, it is hampered by misaligned policies and the water crisis itself.

Reframing the economics of water: Shaping markets for efficiency, equity, and environmental sustainability

We need a new water economics to redefine the way we value water and govern the water cycle as a global common good. At its heart is the recognition of the connection between environmental sustainability, social equity, and economic efficiency.

Historically, these "Three 'Es'" (3Es) have been pitted against each other. The GCEW envisions the 3Es as interdependent, equally important, and best implemented together through a more robust economics.

A core shift is to correctly price water and allocate subsidies to achieve both its efficient use and access for all. The widespread under-pricing of water today encourages its profligate use across the economy. It can also quite unwisely skew the locations of the most water-intensive crops, and water-guzzling industries such data centres and coal-fired power plants, to areas most at risk of water stress. Further, we must recognise the value of green water, including its co-benefits, in decisions on land use planning.

Water is often taken for granted as an abundant gift from nature, when in fact it is scarce and costly to provide to users. Economic modelling tells us adjusting water tariffs to account for water scarcity and its externalities can drive significant GDP gains, particularly in water-scarce, low- and middle-income countries. Proper pricing reduces wastage, promotes more productive use, and ensures that water is treated as the valuable resource that it is.

This impact can be amplified by eliminating harmful subsidies in water-intensive sectors or redirecting them towards water-saving solutions and providing targeted support for the poor and vulnerable. By doing so, we can unlock a triple dividend: improved water management enables greater prosperity and economic growth, the benefits are pro-poor and enhance equity, and environmental sustainability is promoted through improved management of water resources.

To actively put the 3Es at the centre of our response, calls for recognising the power of economic incentives in promoting better stewardship of water resources. This must include recognising both the positive externalities that contribute to the full value of water, including multiple benefits of a stable hydrological cycle, and tackling the negative externalities caused for example by water pollution and over-abstraction. Further, our economic framing should shift from sorting out problems after the damage has been done to preventing them from occurring in the first place. We should shift from fixing externalities after the fact to shaping economies, so that water is allocated and used efficiently, equitably, and sustainably from the start.

Indeed, markets across our economies – from agriculture and mining to energy and semiconductors – must be reshaped to achieve this. Opportunities for innovation around our water challenges need to be assessed not in terms of short-run costs and benefits but in terms of how they can catalyse long-run, economy wide benefits and hence dynamic (rather than static) efficiency gains. This requires understanding the dynamics of increasing returns to scale, where cumulative investments generate learning, innovation and cost reductions.

Five mission areas to address the water crisis

To radically transform both water use, and supply requires a shift from siloed and sectoral thinking to an economy-wide approach to the entire water cycle including both blue and green water, that shapes and crowds in innovations. It will require new commitments from many actors and sectors and new roles for governments – including a mission-oriented approach to meeting the most fundamental water challenges. The GCEW offers five such missions, as critical adaptive pathways towards safe and just water futures.

It means reorienting the policy tools – pricing, subsidies, regulations, procurement, grants, loans – and the roles of the institutions, such as public development banks, water utilities, state-owned enterprises, to achieve these critical goals.

Governments can catalyse investments in water in every sector through greater certainty in policies

Zooming in on agriculture in Africa

As climate change advances, we have a critical window for transformation of agriculture in Africa, where food and nutritional demands are certain to grow significantly in coming decades. Many parts of Africa are well endowed with shallow groundwater resources. Around 255 million people in poverty live above this vast and largely untapped resource. This condition presents an opportunity to boost crop yields and build food security without investments in potentially costly, environmentally damaging and socially disruptive large storage dams. The availability of affordable solar-powered pumps enables farmers to draw groundwater at almost zero marginal extraction cost.

These should be combined with effective initiatives and policy incentives to address risks of over-abstraction of groundwater and to groundwater-dependent ecosystems. Steps should be taken to reform land-use and farming practices to conserve soil moisture and scale up rainwater harvesting systems to enhance the resilience of agriculture which is very largely rainfed in Africa. There is ample opportunity to unleash a revolution in more sustainable food production to meet both Africa's and global needs.

and regulation, and especially through patient investment with a long-term direction. They must also establish more symbiotic partnerships with the private sector, including incorporating conditionalities in contracts, such as to ensure high standards of water use efficiency and environmental protection.

Policymaking must become more collaborative, accountable, and inclusive of all voices, especially those of youth, women, marginalised communities, and the Indigenous Peoples who are on the frontlines of water conservation.

We can and must succeed in tackling five missions that address the most important and interconnected challenges of the global water crisis.

Mission 1: Launch a new revolution in food systems

The Green Revolution more than a half century ago significantly increased agricultural yields and lifted large populations out of poverty. We now need another major transformation in agriculture to reshape the reliance on large quantities of water and nitrogen-based fertilisers, so as to sustain the planet, while at the same time strengthening farmers' incomes and delivering nutrition equitably across populations. We must make radical gains in water productivity – maximising yield per drop of water – and in preserving soil moisture.

This can be achieved by scaling up access for traditional farmers to micro irrigation techniques and the use of climate-resilient seed variants and cropping patterns. While water irrigation will inevitably have to grow in the next few decades to meet growing food needs, a combination of these measures is estimated generate savings in irrigated water consumption of a quarter or more by 2050. To work best, the measures should be coupled with regulatory measures to cap water withdrawals, to ensure water savings are not re-channelled back into expanding irrigated areas or used to switch to more water-intensive crops.

It also requires a major step-up in adoption of regenerative agriculture systems to preserve soil health – including by storing organic carbon in the soil and improving soil water retention – with the aim of covering at least 50% of global cropland by 2050. Achieving these systems will require leveraging large agroindustry coalitions to transform supply chains, as well as creating farmer-centred solutions that enhance demand for regenerative agricultural products and restoring sustainable traditional techniques.

Critically too, we must reduce our collective

dependence on water-intensive foods. We should aim to increase the share of plant-based sources to about 30% of proteins in people's diets by 2050, particularly in higher income nations which have high red meat and dairy consumption. Examples already show we can move in this direction through R&D and culinary innovations, and low lift interventions that do not remove a sense of individual choice. This global shift is ambitious, and consumer habits will take time to evolve. However, they are necessary for everyone's good as animal-based foods are major drivers of the agriculture sector's impact on water use, greenhouse gas emissions and natural habitat loss.

Mission 2: Conserve and restore natural habitats critical to protect green water

Changes in land use over the last half century have had the largest negative impact on freshwater ecosystems. Agricultural expansion in particular has been the main driver of deforestation, altering green water's key role in the hydrological cycle, hence impacting rainfall patterns, lowering agricultural yields and threatening food security itself, particularly as 80% of the total cropland and more than half of the world's food production is rainfed.

It is therefore critical to integrate the benefits of green water into how we manage land use and natural habitats and guide investments for their conservation. To safeguard this precious resource, we should aim to conserve 30% of the world's forest and inland water ecosystems and restore 30% of degraded ecosystems by 2030, in line with the Global Biodiversity Framework. Priority should be given to protecting and restoring those areas that can best contribute to a stable water cycle. Efforts must also be made to engage with and support Indigenous Peoples, who are stewards of a quarter of the planet's land and about 40% of remaining natural lands worldwide.

Mission 3: Establish a circular water economy

Wastewater reuse holds significant, untapped potential. About 8% of today's total freshwater withdrawals, close to the total amount distributed by municipalities worldwide, can be reclaimed from wastewater every year. Massive inefficiencies also exist in water distribution, with roughly 40% of urban water lost through leakage, for example from ageing pipelines. The costs saved by minimising these leaks are substantial and could be reinvested to extend the reach of water infrastructure and ensure its regular upgrading.

We must establish a circular water economy that captures the full value of every drop. Industrial strategies that catalyse and shape technologies and systems that are greener, more inclusive, and more resilient are required. For example, breakthroughs in membrane and solvent-based technologies are driving down costs of water recycling, enabling a future where each drop of used water can eventually yield another drop. Treatment and reuse of wastewater within business facilities must also be scaled up and backed by clear regulations and standards to protect public safety. These moves are more beneficial if water saved is directed towards conservation, not towards furthermore intensive water uses.

Beyond just water, wastewater treatment offers the potential to recover valuable resources such as nutrients, energy, heavy metals, and minerals – generating new revenue streams and enhancing the sustainability of our water systems.

Mission 4: Enable a clean-energy and AI-rich era with much lower water intensity

Renewable energy, semiconductors and artificial intelligence (AI) are defining a new economic era. We must ensure their growth does not exacerbate

global water stresses or constrain the benefits they provide.

Water-efficient clean energy solutions are being introduced and must now be scaled up – from waterless cleaning for solar panels, to second-generation biofuels, to water-efficient cooling towers for nuclear and geothermal plants.

Setting higher standards of both energy and water efficiency for producing semiconductor chips and operating data centres will speed up the adoption of viable solutions and spur innovation. Changes are also needed in how the world mines and produces metals which are foundational to both the clean energy transition and AI revolution, especially by scaling up the adoption of closed-loop water systems.

Mission 5: Ensure that no child dies from unsafe water by 2030

We can no longer ignore the large-scale human tragedy, including innumerable child deaths, caused by unsafe water and sanitation. Unacceptably too, the problem of contaminated water continues to grow, undermining water's ecosystem services, economic development, and human well-being.

Cities such as Phnom Penh in Cambodia, Porto Alegre in Brazil and others in China have shown that it is possible to bring water and sanitation to poor and vulnerable communities. However, much more needs to be done in every region to tackle this problem, through solutions for both the resilient supply of clean water and its more efficient and equitable use.

We need a paradigm shift to ensure access to rural and hard-to-reach communities. Advances in technologies and capacity-development have reached a point where decentralised water treatment and sanitation systems are a viable complement to centralised utilities. Affordable, off-grid water treatment solutions can now deliver clean water to these communities, and with much less discharge or pollutive sludge. Low-cost point-of-use chlorination can also be scaled up in low-income countries.

National public finance and central government funding should support decentralised systems and provide technical assistance to local districts to enhance water and sanitation capabilities.

It is also vital to rebuild resilience in water supply by restoring and expanding wetlands and other natural storage solutions.

Equally, utilities and governments must manage water demand more effectively and equitably, and improve cost-recovery so as to enable continuous maintenance and investments. Tariff and subsidy structures should incentivise water conservation particularly by the largest users while supporting the poor.

Critical enablers of change

The GCEW has identified critical enablers to successfully tackle these five missions. They reflect key dimensions of the critical new way of governing, nationally and internationally, to benefit both people and the planet.

Govern partnerships, property rights, and contracts for an efficient, equitable and sustainable future

Around the world, in cities and countries there is an unfulfilled need for (forging) enduring partnerships to deliver efficient, equitable, and environmentally sustainable water solutions.

Among water utilities, both public and private operators have frequently struggled to provide cost-effective, accessible, and resilient services. Symbiotic partnerships, with collaborative decision-making and contract designs that steer the private sector towards public value creation, and with an appropriate sharing of risks and rewards, can address this need.

Importantly, regulatory frameworks must focus on outcomes-based performance measures, regarding both operational efficiencies and long-term system resilience. Regulators should also enable regular tariff adjustments to reflect the true costs of water provision and support timely maintenance and reinvestment, without comprising incentives for operational cost-efficiency. They should allow investors to achieve viable economic returns, whilst guarding against monopolistic pricing.

We must also recognise the impact of legacy water rights tied to property ownership or special interest influences, which have especially affected Indigenous Peoples and local communities without modern titles to land.

Solutions may include renegotiating existing contracts, setting conditions on new agreements, and preventing water rights from becoming entrenched as quasi-property rights that hinder necessary reallocation efforts.

Shape finance for a just and sustainable water future

Water, as a sector, and water efficiency across every sector, remain severely underfunded. Achieving SDG 6 alone will require around $500 billion per year in additional investments in low- and middle-income countries. Yet, this funding gap is only part of the story. Far greater investments are needed to conserve both blue and green water and scale up innovations for more efficient water use across agriculture, industry, mining, and other sectors that are critical for stabilising the water cycle – underpinned by the new economics of water advocated in this report.

Public investment in water security suffers from puzzling neglect, in too many countries. All too often, the approach to water infrastructure has also been short-term and reactive, leading to neglected assets, frequent service disruptions and leakage – culminating in higher long-term costs.

Private investment in the water economy has been sparse, and most so in developing countries. The under-pricing of water in many cases weakens the case for investment. Investors have also been deterred by the high upfront investments and long payback periods typically required in water infrastructure, without the regulatory consistency that is needed to reduce risks.

We need a new understanding between governments and private investors, to reduce and ensure a fair distribution of risks, and to raise the quantity, quality and reliability of finance for water.

Governments – national and local - need to provide for realistic tariff adjustments and greater certainty in policies and regulation, as well as reprioritise investments in water in public finance itself. There is also a large opportunity to reduce and redirect the massive direct and indirect financial subsidies which currently contribute to the overuse of water and pressure on the hydrological cycle. Environmentally unsound and inefficient subsidies in agriculture and water and sanitation are estimated to be at least US$700 billion per year.

The discount rates used to assess investments in water infrastructure and ecosystem preservation should take into account their long term – including intergenerational – social, economic and environmental benefits. Further, there has to be concerted effort to recognise the value of green water, which is essential to develop schemes for Payment for Ecosystem Services.

Development banks – national, regional, and multilateral – must also be regeared to play catalytic roles across their activities, to mobilise vastly greater amounts of private finance, including the patient, long-term finance for water infrastructure projects.

We should establish Just Water Partnerships to ensure larger and more reliable financing of water in low and lower- middle income countries to expand water infrastructures and scale up innovations, serve vulnerable communities and protect ecosystems. These partnerships, involving development finance institutions and national authorities, should seek to build capacity and strengthen the pipeline of water projects to mobilise investments and manage water sustainably. They should make more active and bolder use of the menu of instruments available to catalyse private investments, including first-loss guarantees, concessional finance, and co-investment arrangements. There is also untapped potential for diversifying risks, by bundling water projects across sectors and countries, to attract funding from institutional investors.

Harness data as a foundation for action

Data is critically needed to transform how we value and govern water.

- For governments, water data is key to sustainable water management at every scale – from river basin to inter-basin to sensitive evaporationsheds. Robust water metrics allow governments to estimate externalities and hold polluters accountable for the harm they cause. They also support early warning systems for climate and water extremities.

- For private entities, data is essential for mitigating water and climate risks in their operations and supply chains, and steering investment towards practices that are just and sustainable and do not destabilise the hydrological cycle.

- For citizens, access to good water data empowers them to engage in water-related decision-making and contribute to the development of locally relevant solutions. It also enables consumers to make informed choices, which could influence corporate decisions.

The water data landscape today is highly fragmented and has large gaps. Alarmingly, data collection, quality and comparability have declined in recent years.

We should work towards a new global water data infrastructure to enable science-based decision making, using and building on data at every level of the water cycle including local and Indigenous knowledge. To achieve this goal, data collection within water basins and globally, and interoperability of data reporting must be strengthened to ensure methodological consistency and the capacity to benchmark outcomes and thus highlight best practices.

We should also generate momentum for market-based disclosure of corporate water footprints through actions by coalitions involving the private sector and civil society organisations, and expedite work towards regulatory standards that mandate disclosure, taking lessons from the journey towards carbon disclosure. Regulatory requirements should aim to throw light on the double materiality of companies' dependence on water as well as the impact of their operations on water resources and land use changes.

Crucially too, we must develop pathways to value water as natural capital. Though still in its early stages, this initiative is an important enabler for responsible stewardship of freshwater ecosystems, and for recognising the interconnection between conserving water and reducing carbon emissions. It also enables governments and all stakeholders to evaluate the costs and benefits associated with land conversions, conservation, and restoration projects.

Build global water governance

As we have highlighted, water runs through virtually all the SDGs, impacting economies and human well-being everywhere. Further, the hydrological cycle transcends local and national boundaries, connecting us all. And water problems are reinforcing climate change and the loss of biodiversity. Yet, our current multilateral governance of water is fragmented, incomplete and ineffective.

The UN has recently adopted the UN System-wide Strategy for Water and Sanitation focused on accelerating progress to achieve SDG 6. There are also existing legal arrangements, such as the UNECE Convention for the management of the transboundary rivers and lakes, which however only address blue water for riparian states, overlooking the critical role of green water in ecosystem and climate regulation, food security, and its interactions with blue water. It is time to consider whether and how similar governance arrangements could be applied to atmospheric moisture flows, for instance drawing inspiration from the UNECE Convention on long-range transboundary air pollution, both in its process and outcomes.

The ultimate ambition for global water governance should be the establishment of a Global Water Pact. It should recognise that water is both a local and global issue, and the hydrological cycle, encompassing both blue and green water is a collective and systemic challenge. The Pact should set clear and measurable goals to stabilise the hydrological cycle and safeguard the world's water resources for a sustainable and just water future. However, the path to such a Pact requires a careful and multi-stakeholder approach, identifying intermediate milestones and enhancing existing conventions both in water and related sectors, building on the three Rio conventions – the convention on Biological Diversity (CBD), the United Nations Convention to Combat Desertification (UNCCD), and the United Nations Framework Convention on Climate Change (UNFCCC), as well as the Ramsar Convention on Wetlands.

Reforms to global water governance must be complemented by public sector capacity building at the local, regional, and national levels. Governments require the administration and implementation capacity to design, develop, and deliver water missions with a focus on designing more symbiotic partnerships and financial arrangements and ensuring the effective governance of data and utilities.

The five critical water missions identified by the GCEW provide a starting framework. Around each of them, coalitions from public-private-philanthropic partnerships can draw on diverse expertise to tackle the water challenges. These coalitions could contribute to a broader multilateral process in the longer term. For instance, the World Bank's Global Challenge Program on water, "Fast Track Water Security and Climate Adaptation", seeks to mobilise public and private sector resources across three broad pillars: (i) universal access to water and sanitation (ii) irrigation and water management, (iii) climate adaptation and resilience.

Addressing the root causes of the local to global water crisis, revaluing water, governing the hydrological cycle as a global common good and spurring innovative solutions, means recognising the necessity of a dialogue process that paves the way for a Global Water Pact. Such an ambitious dialogue process must involve engaging all sectors and all voices, particularly those marginalised or disproportionately affected by water scarcity and degradation, including Indigenous Peoples and local communities, women, and youth. It also means shaping a common understanding by including diverse and local perspectives of water management. It must lead to a clear action agenda, a methodology for institutional innovation and development of the capacities to see it through.

Turning the tide for a just and sustainable water future

Humanity needs a new course for water at every scale: from local sources to river basins, from national to transboundary and globally in multilateral cooperation.

The challenges we face are far from insurmountable. We can and must transform them into an immense global opportunity. One that drives economy-wide innovation and prosperity. One that forges a new social contract among all stakeholders. One with justice and equity at the centre of its efforts.

Our commission's work and proposals are just the beginning. They chart a new economics for a future where water efficiency and security can be achieved for all, where ecosystems are protected, and sustainable development can be realised, everywhere. We can turn the tide on the water crisis and create a more resilient and equitable world for generations to come.

Recommendations

The GCEW offers a set of recommendations, to value and govern water so as to stabilise the hydrological cycle, enable food security and human dignity, and keep the Earth system safe for humanity. Underpinning all our recommendations is the need for justice and equity to be key principles intrinsic to managing water more efficiently, dynamically and sustainably, and not merely an add-on.

1. We must **govern the hydrological cycle as a global common good**, recognising our interdependence through both blue and green water flows; the deepening interconnections between the water crisis, climate change, and the loss of the planet's natural capital; and how water flows through all our 17 Sustainable Development Goals.

2. We must **recognise the minimal water requirements of water for a dignified life. This report offers 4,000 l/p/d as a reference for further discussion.**

- New water provision should focus on those left behind first.

3. We must **value water, the Earth's most precious resource, to reflect its scarcity, ensure its efficient and equitable use, and preserve its critical role in sustaining all other natural ecosystems**.

- We must price water properly to incentivise its conservation, particularly by the largest users. Today's massive subsidies that contribute to water's overuse in many sectors and environmental degradation should be redirected towards water-saving solutions, protecting and restoring freshwater ecosystems, and ensuring access to clean water for vulnerable communities.
- We must account for the impacts of industrial, national and global development on both blue and green water resources.
- We must also embed the value of green water systematically in decisions on land use so as to better protect evapotranspiration hotspots such as forests, wetlands, and watersheds. Measuring green water's benefits, including its co-benefits, can also enable schemes for Payment for Ecosystem Services.

4. We must **shape markets to spur a wave of mission-oriented innovations, capacity-building and investments across the entire water cycle**, including blue and green water, to radically transform how water is used, supplied, and conserved. These investments must be **evaluated not in terms of short-run costs and benefits, but for how they can catalyse dynamic, long-run economic and social benefits**.

5. We must **forge partnerships** between all stakeholders, from local to global, **around five missions that address the most important and interconnected challenges of the global water crisis**, and must drive innovation in policies, institutions and technologies:

- **Launch a new revolution in food systems** to improve water productivity in agriculture while meeting the nutritional needs of a growing world population.
- **Conserve and restore natural habitats critical to protect green water.**
- **Establish a circular water economy,** including changes in industrial processes.
- **Enable a clean-energy and AI-rich era with much lower water intensity.**
- **Ensure that no child dies from unsafe water by 2030,** by securing the reliable supply of potable water and sanitation for underserved communities.

6. We must forge **symbiotic partnerships between the public and private sectors to deliver efficient, equitable, and environmentally sustainable use of water from the start**.

- Governments should incorporate conditionalities in contracts and property rights to ensure high standards of water use efficiency and environmental protection, including corporate responsibility for watershed and water basin conservation programmes. They should also provide certainty for investors through clear and consistent regulation and policies, including realistic tariff adjustments.

- For utilities, collaborative decision-making and contract design can steer the private sector toward public value creation with appropriate risk and reward sharing. The focus of partnerships should be on outcome-based performance for operational efficiencies and long-term system resilience.

7. We must **raise the quantity, quality and reliability of finance for water in every sector**.

- **Government budgets themselves must reprioritise investments in water, and repurpose today's environmentally harmful subsidies,** estimated at over US$700 billion per year in agriculture and water and sanitation alone. The discount rates used to assess investments in water infrastructure and ecosystem preservation should take into account their long term - including intergenerational - social, economic and environmental benefits.

- **Development finance institutions (DFIs) – national, regional, and multilateral – must be regeared to provide catalytic finance** to unlock vastly greater amounts of private finance, including more patient finance for water infrastructure projects.

- **Just Water Partnerships involving DFIs and national authorities should be established to build capacity and mobilise investments for low and lower-middle income countries.** There is large untapped potential for doing so, such as by leveraging concessional finance and pooling risk through bundling projects across sectors. Also key in creating an enabling environment for financing is to build a pipeline of bankable projects, consistent with holistic, programmatic approaches and national development strategies.

8. We must **harness data as a foundation for action** by governments, businesses, and communities.

- We should work towards **a new global water data infrastructure, building on and strengthening capacities for data collection on blue and green water at every level of the water cycle**, from local to river basin to global. It should include local and Indigenous knowledge, and aim for interoperability of data reporting.

- We must **accelerate efforts toward market-based disclosure of corporate water footprints, and expedite work towards regulatory standards for mandatory disclosure**, so as to steer action toward sustainable water practices. The aim must be providing transparency on the double materiality of water risks posed by companies' operations – including both their own vulnerabilities, and the impact of their operations on blue and green water resources. We recommend that **water disclosure be integrated in carbon transition plans** and be an integral part of sustainability-related disclosures.

- We must develop pathways to **value water as natural capital to enable responsible stewardship of freshwater ecosystems**, including enabling governments and all stakeholders to evaluate the costs and benefits associated with land use changes.

9. We must build **global water governance that values water as an organising principle, recognises that water is both a local and global issue, and that the hydrological cycle encompassing both blue and green water is a collective and systemic challenge**.

- The **ultimate ambition should be the establishment of a Global Water Pact** that sets clear and measurable goals to stabilise the hydrological cycle and safeguard the world's water resources for a sustainable and just water future.

- To achieve such a Pact, we need a **multi-stakeholder approach that provides for a clear action agenda, institutional innovation, and capacity building**.

- The five critical water missions offer a starting framework for developing public-private-people coalitions, drawing on diverse expertise and engaging with all sectors and voices, including Indigenous Peoples and local communities, women, and youth.

- Water and its values should be anchored in every convention, including climate, biodiversity, wetlands, and desertification, and UN agreement, with clear goals and targets.

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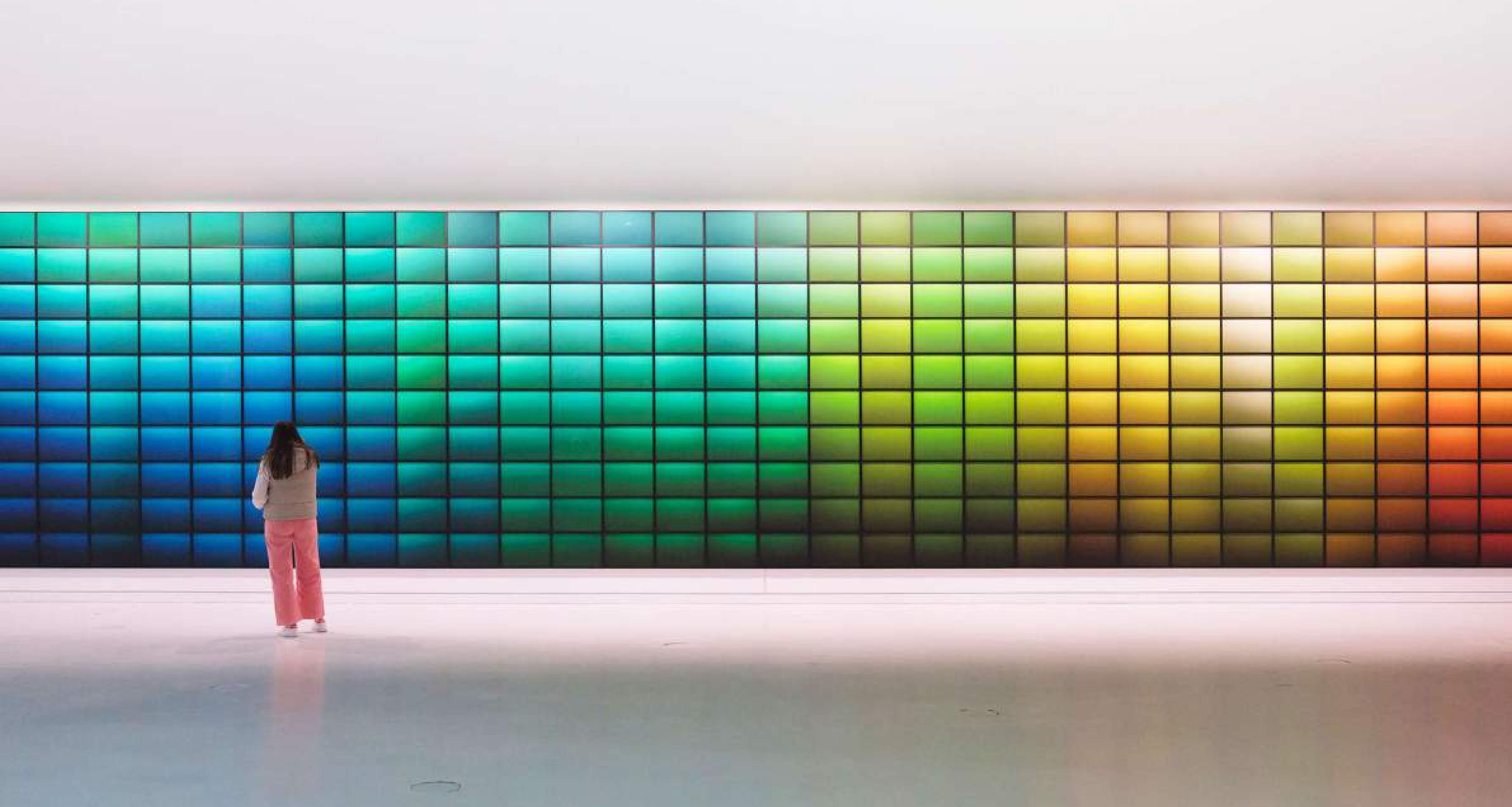
Nicolas Floc'h, Ocean Rivers – Mississippi, The Color of Water, Water Columns from 0 to -100 m in Depth, Mississippi Delta, from Empire to the Gulf of Mexico (100 km), USA, 2022.

72 photographs extracted from the grid of the delta to the ocean, composed of 516 color photographs organized geographically. Pigment prints, 40 x 56 cm each. Chapelle du Méjan, Rencontres Photographiques d'Arles 2024. Courtesy of Galerie Maubert, Paris.



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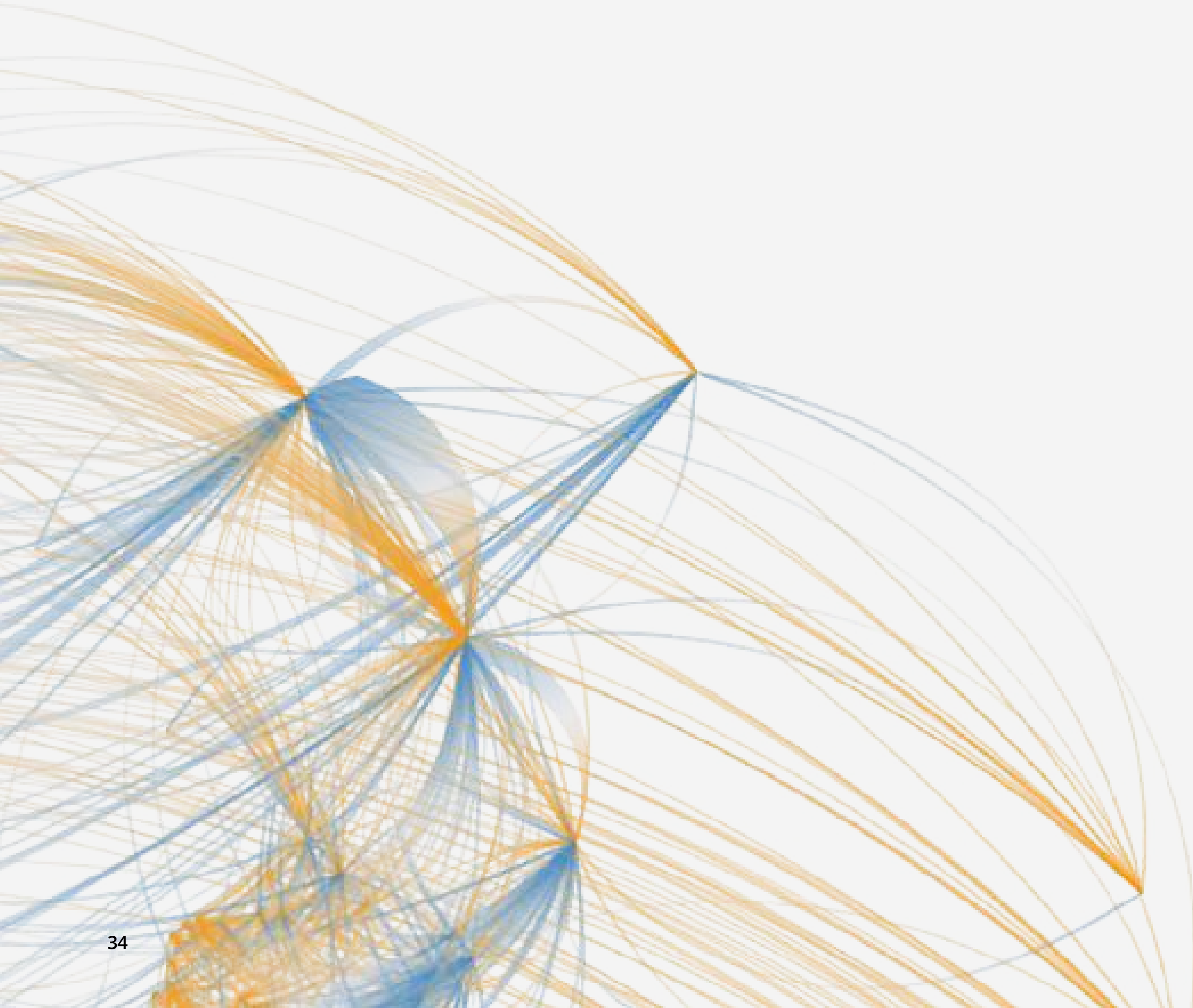
The Global Commission on the Economics of Water is an independent commission. The co-chairs and the Commissioners each contributed in their personal capacities. The co-chairs took final responsibility for the contents of the Report, while Commissioners contributed actively with substantive inputs and comments. The outputs of the Global Commission (reports, executive summary, infographics, other communication materials) do not necessarily reflect in their entirety the views of the respective Commissioners or those of their respective institutions.

1. Introduction: Transforming the world's understanding of the economics of water



Water moves around the globe in a complex and often invisible manner known as the hydrological cycle. Life, as we know it, relies on this cycle and impacts it at the same time. As this report explains, the world faces unprecedented changes to precipitation – the source of freshwater – with consequences for local and global well-being, today and for all generations to come.

A narrow view of the scale and scope of water, its connection across livelihoods and with each of the Earth's ecosystems, has resulted in economic systems and incentives that misalign with the true and multiple values of water, which cultures and societies around the world have held for generations. The failure to acknowledge the economic, environmental, and societal contributions of water remains a significant obstacle to local and global progress, including realising the United Nations (UN) Sustainable Development Goals (SDGs) and ambitions to mitigate climate change.

The Global Commission on the Economics of Water (GCEW) calls for bolder thinking and more integrated policy frameworks locally and globally. We seek in this report to advance a new economics of water:

- One that recognises the hydrological cycle as a global common good, understanding that it connects countries and regions through both the water that we see and atmospheric moisture flows; that it is deeply interconnected with climate change and the loss of biodiversity with each rebounding on the other; and that impacts virtually all the SDGs.

- One that transforms water governance at every scale, from local to river basin to global, to ensure it is managed more efficiently, delivers access and justice for all, and sustains the Earth's ecosystems.

- One that brings together fundamental economic concepts and tools, most critically to value water properly to reflect its scarcity and the multiple benefits it provides as the Earth's most precious resource.

- One that tackles externalities caused by the misuse and pollution of water but shifts from fixing them after the fact to shaping economies so that water is used efficiently, equitably, and sustainably from the start.

- One that spurs a wave of innovations, capacity-building and investments, evaluating them not in terms of short-run costs and benefits but for how they can catalyse long-run, economy wide benefits and hence dynamic efficiency gains through learning, scale economies and cost reductions.

- One that recognises that the costs entailed in these actions are very small in comparison to the harm that continued inaction will inflict on economies and humanity.

The GCEW set out to recast the economics of water, mapping the systemic links of the hydrological cycle to land, climate change, biodiversity loss, and progress on the SDGs. This report explores and proposes how we can re-define and re-value water as a critical planetary resource and manage the hydrological cycle locally and as a global common good. It highlights changes to the hydrological cycle, including the drivers of change, impacts, and consequences across scales and geographies. It provides the evidence and opportunities for systemic action to address the world's most important water missions and sets out the critical enablers required for these transformations.

The report follows two major reviews that spurred action across scales in response to climate change and the loss of biodiversity: the Stern Review on the Economics of Climate Change (2006), and the Dasgupta Review on the Economics of Biodiversity (2021). Both took on the challenge of re-imagining the way our economies interact with the climate and biodiversity, respectively, in the face of global environmental changes that pose significant risk to our well-being and way of life for generations to come. The Stern Review demonstrated the cost of failing to act on climate change and highlighted that the benefits of strong and early action far outweigh the economic costs of inaction. The Dasgupta Review offered a new framing for how we think about and measure success in our economies in a world where the biosphere is finite and provided a language for understanding our engagement with nature.

The economics of water is inseparable from the economics of climate change and biodiversity. This report builds on the approaches of both these preceding reviews, as well as a global engagement around the UN 2023 Water Conference and its follow-up actions. It shows that the cost of inaction on the water crisis and recent changes in the global hydrological cycle is high, but that action is possible – and unavoidable if the world is to continue to enjoy the myriad benefits water provides. The report demonstrates the bounds within which we operate when it comes to the stability and reliability of water sources and recognises the need to balance our demands with the ability of the hydrological cycle to supply them. Crucially, it recognises the need to value water as the essential resource it is: a systemic, irreplaceable source of life that underpins all human existence, the entirety of our natural assets, and economic activity.

Climate change and the loss of biodiversity are now considered critical global challenges and included in conversations beyond environmental circles. However, the water crisis and implications of a destabilised hydrological cycle for the shifts in the global environment, remains misunderstood or sidelined.

This report argues for water's central role in conversations around environmental change, governance, and economic decision-making at all levels. Its analyses build on previous international reports and existing international agreements that govern water resources. However, one of the report's fundamental conclusions is that the governance of water resources represents a much larger challenge than previously highlighted. It requires coordinated and integrated policies, across every economic sector, that connect to both climate

and biodiversity, with recognition of the broad set of water's function and services.

While the report presents an integrated assessment of water resources based on the latest evidence, it also recognises the work that remains to be done. It is unsurprising that much of the failure to address this challenge lies in the failure to use economic instruments appropriately and develop policy responses that address water's different economic aspects and avoid injustices. The report sets out the opportunity to improve the use of these tools to frame economic incentives in ways that purposely tackle the urgency and scale of the challenges at stake, reflect the changing hydrology and state of resources, ensure efficient water use in all sectors, shape equitable access and sustainable water uses, and safeguard water for nature and environmental processes.

The members of the GCEW have benefited from the work, analysis and expertise of dozens of researchers and the contribution of countless experts from around the world, and across sectors and backgrounds. The diversity of experience and knowledge on the Commission enabled valuable debate, allowing the GCEW to step out of the mainstream and to shape a new economics of water. As members of the GCEW participated in their independent capacities, the resulting report also does not reflect the views of any one institution or government. Indeed, the world's growing vulnerability to water risks will increasingly require collaborative processes such as this.

The report provides a strong foundational assessment of the physical changes in global water endowments and their economic consequences, why such changes have occurred, and how the water crisis and threats to the hydrological cycle can and must be addressed.

The report represents ways of thinking about economics, water and the hydrological cycle from across the GCEW, based on the best available science and economics, in a body of work that can continue to be built upon.

Until now, water has been governed and managed as if water resources are only local and steadily rechargeable year after year, factoring in only natural variability based on historical data. Chapter 2 presents evidence that this assumption no longer holds. We live in a world of more frequent and extreme water-related disturbances, and of life-supporting systems losing water resilience. We already feel the impact of an altered hydrological cycle and its interactions with atmospheric dynamics, with increasing frequency and severity of droughts and floods around the world.

The evidence presented in Chapter 2 highlights the need to recognise that the hydrological cycle comprises both "blue" and "green" water and must be managed as a global common good. Current approaches to water policy tend to deal with the blue water we can see – in rivers, lakes, and aquifers – largely overlooking green water – in soil, plants, and forests. Green water evaporates and transpires into the air, and recycles through the atmosphere, generating around half of all precipitation on land. These interdependencies take three main forms.

First, countries and communities are interdependent through the dynamics of the hydrological cycle at different scales. Water travels long distances: atmospheric moisture flows connect regions across borders, continents, and oceans in patterns that shift with the prevailing winds and rarely match the geographical complexity of surface water and

aquifer basins. The science of terrestrial moisture recycling helps us understand how local action – typically change to land use and natural habitats – can affect rainfall in other parts of a country or distant regions. Precipitation is determined by local actions not only where rain falls, but where it originates. The evidence in Chapter 2 shows that atmospheric moisture extends the scope of our understanding of how water moves. Managing water as a resource is much more than a local matter.

Second, the global hydrological cycle is deeply interlinked with the climate and biodiversity crises. Chapter 2 makes clear that we must redefine the relationship between water and climate. While the emphasis has always been on adaptation, the hydrological cycle is both impacted by and a compounding factor of the climate crisis. The stability of the water cycle is governed by Earth's energy balance and land use, determining the partitioning of precipitation in runoff and evapotranspiration. When green water is mismanaged and lost through deforestation and unsustainable land use, future precipitation is impacted and carbon storage is reduced in the soil and vegetation. Beyond climate change, the water crisis is deeply intertwined with biodiversity loss and desertification, both recognised as systemic and global issues. Droughts and floods exacerbate soil erosion and land degradation, which can create vicious cycles – ever-less-fertile soil that cannot support vegetation or absorb rainfall, more green water lost, and more land cleared to grow crops – inflicting damage on communities and all life. It follows that water should play a much more prominent role in national strategies to mitigate climate change and biodiversity loss.

Third, water plays a direct and indirect role in achieving all the SDGs, which are crucial for a thriving human species and global prosperity. Most economic activities and thus livelihoods depend on access to water. Globally, 80-90% of all blue water withdrawals are used for irrigation and 10% of freshwater withdrawals are used for urban purposes. Because water is essential to all the SDGs and the entire economy, the actions and choices made in a wide range of sectors affect water resources in profound ways often causing social injustices. Water is therefore not a sector that can be managed in isolation.

In a world of human-induced changes to resource dynamics, managing water as a global common good is an opportunity to mobilise collective action on a systemic and economy-wide basis. Without fully engaging people, communities, and countries in approaching the hydrological cycle as a global common good, water governance will fail to ensure the stability and integrity of this precious resource.

The economy is a thirsty system, and water is a critical economic input. The GCEW notes that policy incentives are seldom aligned with the economic, social, and environmental forms of value that water provides. Current systems for managing water resources are often not fit for purpose and have resulted in an unacceptably high human, environmental, and economic toll. The Earth system is therefore losing resilience: the ability to keep environmental and water conditions stable and conducive for human development. As demand increases, global populations rise, and climate change intensifies, the challenges will increase, requiring ever more urgent reforms and new policies.

Chapter 3 provides the foundations for a new economics of water. It highlights the forces driving the water crisis, from increased consumption to climate change and land-use shifts. It demonstrates how the intersection of changing water supplies and rising demand for water pose significant risks to human well-being and progress. New observational data, combined with new methods of analysis find that this is particularly true in countries that are water-dependent and where water scarcity is already a pressing issue, and reveals the stark consequences of inaction.

Aligning economic incentives to reflect the value generated by blue and green water provides a new perspective on how we govern and value water for the common good, combining economic efficiency, social equity, and environmental sustainability. Achieving any one of these outcomes requires achieving the other two as well. Placing these three objectives on equal footing represents a clear divergence from practices that came before, where environmental sustainability was considered a second order concern and equity subordinate to economic efficiency.

Achieving these objectives requires recognising the power of economic incentives to generate benefits from the use of water, address the risks that arise from water stress and correct externalities such as water pollution. The report also calls for complementary approaches that shift from a focus on fixing problems after the damage has been done, to avoiding problems from occurring in the first place. Prevention is typically more cost effective than the cure, which suggests the need to shape markets to use and allocate water more efficiently, equitably, and sustainably from the start.

The second half of the report looks at how to put this knowledge into practice, identifying the need for a significant shift in water governance. This shift is guided by three overarching priorities to support a new perspective on governing water:

- Value water for the essential services it provides. Water is rarely priced in ways that reflect its scarcity and contribution, and it is therefore used wastefully and seldom allocated to its most beneficial uses. Any policy regime would need to include safeguards to assure adequate access for poor households and environmentally sustainable and prudent uses.

- Absolute limits are critical to ensuring sustainability. Acknowledging that water systems are renewable, finite, and vital resources implies that there are absolute limits to the amount of blue and green water that can be safely and sustainably consumed.

- Policy packages can promote synergy. No single policy can achieve the multiple goals of efficiency, equity, and environmental sustainability. Policy packages will be needed to address the trade-offs likely to emerge.

Chapter 4 advances the economics of water with a view to responding to the 21st Century challenges that this report brings into focus. To ensure that these developments lead to the systemic, collective, and economy-wide action demanded by the global water crisis, they need to be underpinned by a new, less reactive, and more proactive economic framing. We must shift from fixing market externalities after the fact to shaping economies so that water is allocated efficiently, equitably, and sustainably from the start. Indeed, markets across our economies – from agriculture and mining to energy and semiconductors – need to reshape their water use and impact on the hydrological cycle, including pollution, embedding outcomes-orientation and directionality.

The conception of states as market-fixers has led to the idea that governments are not supposed to steer the economy, only enable, regulate, and facilitate it. To tackle the global water crisis in an economy-wide way, this report proposes a mission-driven approach to policymaking, bringing multiple sectors together to tackle shared objectives. Missions are ambitious, clear, and time-bound objectives that mobilise cross-sectoral solutions to difficult challenges. They focus on outcomes, as opposed to outputs, and in doing so, missions can target challenges that do not necessarily have pre-defined, technological fixes. Solving these challenges therefore requires a bottom-up approach, exploring many possible solutions and mobilising economy-wide innovation, investment, and partnerships. This approach is adaptive, cross- sectoral, inclusive, and firmly committed to economic efficiency, justice and sustainability.

Part 2 considers what a mission-centred approach means for water and examines the policy levers that can be used to tackle the water crisis locally and globally. Chapter 5 identifies five critical water mission areas that must drive innovation in policies, institutions, and technologies to radically transform how water is used, supplied, and conserved:

- Launch a new revolution in food systems.

- Conserve and restore natural habitats critical to protect green water.

- Establish a circular water economy.

- Enable a clean-energy and AI-rich era with much lower water intensity.

- Ensure that no child dies from unsafe water by 2030.

Together, these missions address the most significant and interconnected challenges of the

3. The first two missions seek a transformation of policies and practices in agriculture and natural habitats, to conserve water whilst enhancing yields to feed a growing world population, and to redress the longstanding neglect of green water and stabilise the hydrological cycle. Recognising that the bulk of humanity live in urban areas where total water storage is unstable and declining, two further missions focus on promoting circular-economy solutions and reducing the water intensity of rapidly growing industries like clean energy and artificial intelligence (AI). Finally, we must never lose emphasis on the need to ensure access to clean water and sanitation for all.

The report sets out the critical enablers to successfully tackle these challenges in Chapters 6 through 10. Chapter 6 sets out how partnerships can be designed with equity, efficiency, and environmental sustainability at their core. Shaping markets requires starting with an objective, then designing property rights, partnerships and financial structures to deliver on that objective from the start, in a pre-distributive way. This requires a lot of attention to contract design and the form of partnerships between actors, especially between government business, which can become more symbiotic. A new approach to partnerships must be based on a new approach to risk: where risks are shared between actors, the rewards should be shared as well.

Finance can be shaped to support water policy ambitions, with benefits across agendas beyond water, at local, national, and global levels. In combination with blue water, attention should be paid to the green water part of the hydrological cycle in the context of climate-change mitigation and adaptation, biodiversity, and forest conservation. Chapter 7 looks at how finance can support mission-centred policy, including principles to mobilise and direct financing flows towards water stewardship and the policy shifts required across public, private, and multilateral finance.

Chapter 8 considers the governance of water utilities in the context set out by the GCEW. Cities need to become water-resilient and ensure access for all, through water-use efficiency, reuse, protection, and expansion of blue-green-grey infrastructure to address severe future water shortages and flooding, the growth of untreated wastewater, and climate-change-induced impacts on the urban water cycle. It is imperative to reduce urban water consumption through demand assessment, management, and monitoring to ensure that public health, equitable and affordable water access, and ecosystem health are prioritised. The chapter sets out how water services and utilities can become mission-driven and water-justice-centric to support the missions set out in Chapter 5.

Data can help underpin the transformations needed. Chapter 9 sets out the data landscape, and the gaps and why they exist. It looks at how to unlock the potential of data that is comprehensive, high quality, timely, interoperable, and publicly accessible to face the five missions and achieve the principles set out in Chapter 3.

Finally, Chapter 10 makes the case for water to be considered as an organising principle for sustainable development, and the scaffolding to establish a global water governance mechanism to ensure a comprehensive strategy to deploy collective local to global action on water.
The chapter explores the complexity of the challenges of water governance, and the role of international institutions in global water governance. While high-level leadership is necessary, it must be complemented by robust, participatory, and bottom-up approaches. Multiple perspectives must be brought to the table, including civil society groups, front-line communities, citizens and individual water users, and private sector actors.

The conclusion builds on all chapters of the report, to offer a suite of principles fit for current and future challenges. These principles, in line with the ambition of the GCEW, are set to address the water crisis and beyond, contributing to global agendas. These principles provide the basis for further discussion and refinement, as well as opportunities for action beyond the work of the Global Commission.

1. The hydrological cycle, encompassing both blue and green water, has to be governed as a global common good, through concerted action in every country and collaboration across boundaries and cultures.

2. There are absolute limits to the total amount of water that can be safely and sustainably consumed globally.

3. Water must be an organising principle for the transformations required to achieve collective ambitions on sustainable development, and global environmental ambitions, regarding climate change, biodiversity and desertification.

4. Economic efficiency, social equity, and environmental sustainability are mutually supportive. They can only be achieved through a range of policy packages, because no single policy alone can achieve the three of them.

5. Water must be priced, subsidies allocated, and regulations shaped to support both efficient water use and affordable access for all. Further, the full value of water's ecosystem benefits, including those deriving from green water, must be built into decisions on land use and protection of natural habitats.

6. We should also shift from fixing externalities after the fact to shaping economies, so that green and blue water is used efficiently, equitably, and sustainably from the start.

7. An outcomes-focused approach centred on our most important and interconnected water missions, must drive coordinated actions by governments, the private sector, and communities.

8. Every human being needs water for a dignified life, estimated at 4000 litres per person per day. This estimate needs to be refined, promoted and achieved.

2. The hydrological cycle as a global common good

Key takeaways

The growth of consumption and linked changes in land use and pollution are impacting the quantity and quality of freshwater resources. Climate change, deforestation, and loss of biodiversity are mutually reinforcing drivers of shifts that are changing precipitation patterns— the source of all freshwater— and destabilising the hydrological cycle.

Current policy tends to deal with the "blue" water we can see – in rivers, lakes, and aquifers – largely overlooking "green" water – in soil, plants, and forests – that evaporates and transpires into the air, falling downwind as rain.

Green water supplies are far more interdependent than previously thought. Atmospheric moisture flows carry water from one country to another, even across continents and oceans.

We are failing to connect the feedback between land cover and rainfall as a critical component of the global hydrological cycle. Nearly half the rain that falls over land originates from the land through a process of "terrestrial moisture recycling". Intact ecosystems and lands managed in ways that do not adversely impact their hydrological functioning are critical to securing terrestrial rainfall. A stable supply of green water in soils is also crucial for carbon sequestration.

The hydrological cycle is deeply interlinked with climate change. As global temperature rises, land and oceans respond by evaporating more freshwater, and the hydrological cycle intensifies, leading to more extreme weather events that affect billions of people.

Multiple signs are pointing to a global freshwater crisis. We have transgressed planetary boundaries for global blue and green freshwater. Regional and local scales face multiple crises in terms of water quantity and quality. Combining information on total terrestrial water storage with indicators of water shortage and physical scarcity reveal "hotspots" of particular concern.

We therefore need to:

- Reframe the hydrological cycle as a global common good as, i) the hydrological cycle renders countries and communities interdependent regionally and globally; ii) the hydrological cycle is deeply interlinked with the climate and biodiversity crises; iii) water plays a direct or indirect role in achieving all the Sustainable Development Goals.
- Value blue and green water for the essential services it provides.
- Put absolute limits on the amount of blue water that can be safely and sustainably consumed.
- Manage green water in a way that acknowledges the feedback between climate change, land cover change, and precipitation. Conserve, restore, and sustainably use ecosystems – especially rainforests and wetlands – whose evapotranspiration is the source of rain at global scales.
- Elevate the role of water in national strategies to mitigate climate change and biodiversity loss.

Humanity is deep into the Anthropocene, with human actions as the main pressure on our planet, impacting the global hydrological cycle and freshwater availability around the world. But global water crises go well beyond human suffering from shocks like droughts and floods, or the growth in the number of people using unsafe and insufficient water. Almost half of the world's population faces some degree of water scarcity, and freshwater will determine whether the United Nations (UN) Sustainable Development Goals (SDGs) are possible to achieve.

While we must address how to manage and allocate freshwater fairly and efficiently, science demonstrates two additional threats to human development. First, we are pushing the water cycle out of balance – beyond the natural bound of variability we have known for the last 12,000 years – changing precipitation patterns, which are the source of all freshwater. Climate change, deforestation, and loss of biodiversity are mutually reinforcing drivers of shifts in the stability of freshwater runoff flows and vapour fluxes, which in turn determine future rainfall.

Second, freshwater provides for the stability of environmental systems on land and thereby the global economy. Without freshwater, there can be no photosynthesis, no biomass (food or fibre) production, no biodiversity, and no land-based carbon sequestration. Further, landscapes tend to burn when they dry out, impacting humans and other species, and increasing greenhouse gas (GHG) emissions. In short, stable freshwater is a prerequisite for economic and ecological resilience at ecosystem, biome, and planetary scale. This makes water a systemic challenge requiring collective, global action and transformations in how freshwater is governed and managed.

We have overused and polluted water resources for generations, causing great injustices to people and other species. Surface water and groundwater bodies are managed as if they are local only and stable year after year, factoring in only natural variability based on historic data. This premise no longer holds. Under growing pressure from human activity, the hydrological cycle is increasingly out of balance in individual countries and regions and on a global scale.

Current approaches to water policy tend to deal with the “blue” water we can see – in rivers, lakes, and aquifers – largely overlooking “green” water – in soil, plants, and forests. Green water evaporates and transpires into the air and recycles through the atmosphere, generating around half of all rainfall on land, the source of all freshwater. Countries are thus connected not only through flows of blue water such as rivers, but also through atmospheric flows of moisture sourced from green water flows from land. We are failing to connect the feedback between land cover and rainfall generation as a critical component of the global hydrological cycle.

A stable supply of green water in soils is crucial to sustaining the natural land-based ecosystems which in turn absorb 25-30% of the carbon dioxide emitted from fossil-fuel combustion (Friedlingstein et al., 2023). This process represents one of the most significant ecosystem services to the global economy. Yet the loss of wetlands and soil moisture, and deforestation are depleting the planet’s carbon stores, with consequences for climate change. Rising temperatures trigger extreme heat waves and increase evaporative demand in the atmosphere, which dries landscapes and heightens the risk of wildfires.

The water crisis impacts virtually every one of the SDGs and threatens people everywhere. The challenge of producing enough food for a growing world population, accelerated spread of diseases, uninhabitable urban areas, and increased forced migration and conflicts are just a few of the predictable and unjust outcomes.

Understanding blue and green water

Freshwater is the "bloodstream" of the biosphere. The global hydrological cycle provides the basis for all life, enabling carbon cycling through the production of biomass, regulating the climate, and carrying nutrients, chemicals and pollutants (Steffen et al., 2015; Gleesen et al., 2020; Wang-Erlandsson et al., 2022).

The global hydrological cycle is the movement of water on, above, and below Earth’s surface. This continuous flow of water is driven by solar radiation and gravity, with water shifting between its physical phases of liquid, gas (vapour) and solid (frozen), and moving between land, oceans and the atmosphere. Water enters the atmosphere either through evaporation from land and water bodies, transpiration from vegetation or evaporation from oceans, where it is then transported as vapour, condensates, forms clouds, and eventually precipitates again on the Earth's surface as rain, snow and hail.

Precipitation is the source of freshwater. Once precipitation falls on land, it can be broadly categorised as blue or green (Figure 2.1). When rain falls on land, it either infiltrates into the soil, creating soil moisture (green water), evaporates directly from the land surface (from the canopy cover, soil or standing water ponds), or flows as surface runoff (blue water) in rills and gullies, feeding rivers and wetlands. Part of the infiltrated green water is taken up by plants, returning to the atmosphere via transpiration (green flow). Water that seeps beyond the root zone in the soil reaches the water table, and eventually deeper layers of groundwater (blue water resource). This groundwater recharge is also in continuous movement, feeding the sub-surface flow of blue water to rivers, lakes, and estuaries.

It is important to distinguish between blue/green water *stocks* and *flows*. Blue water stocks are

Box 2.1 The growing water pollution crisis

Water pollution is increasing globally and becoming more complex. More stringent water quality regulation and significant investments in wastewater treatment (primarily in high-income countries) have led to localised improvements, with major river clean-ups for example on the Han River in Korea, on the Jucar and Segura rivers in Spain or on the Rhine or the Danube in Central Europe. However, these improvements are outweighed by the fact that pollution loads have accumulated in water bodies and soils over the past centuries.

Beyond pollution, attention needs to be paid to the hydro-morphology of water bodies, which sits at the interface between land, freshwater and ecosystems. Few policy initiatives consider it. The European Union's Water Framework Directive is an exception.

Water pollution aggravates water scarcity. Clean water scarcity (defined as the availability of surface water with acceptable quality) affects 55% of the global population for at least one month each year, compared to 47% when only water quantity parameters are considered (Jones, Bierkens, & van Vliet, 2024). Clean water scarcity is projected to rise globally, to between 56% and 66% of the global population by the end of the century (Wang, et al., 2024). Water contamination is projected to aggravate water scarcity in over 2000 sub-catchments worldwide by 2050 (Wang, et al., 2024).

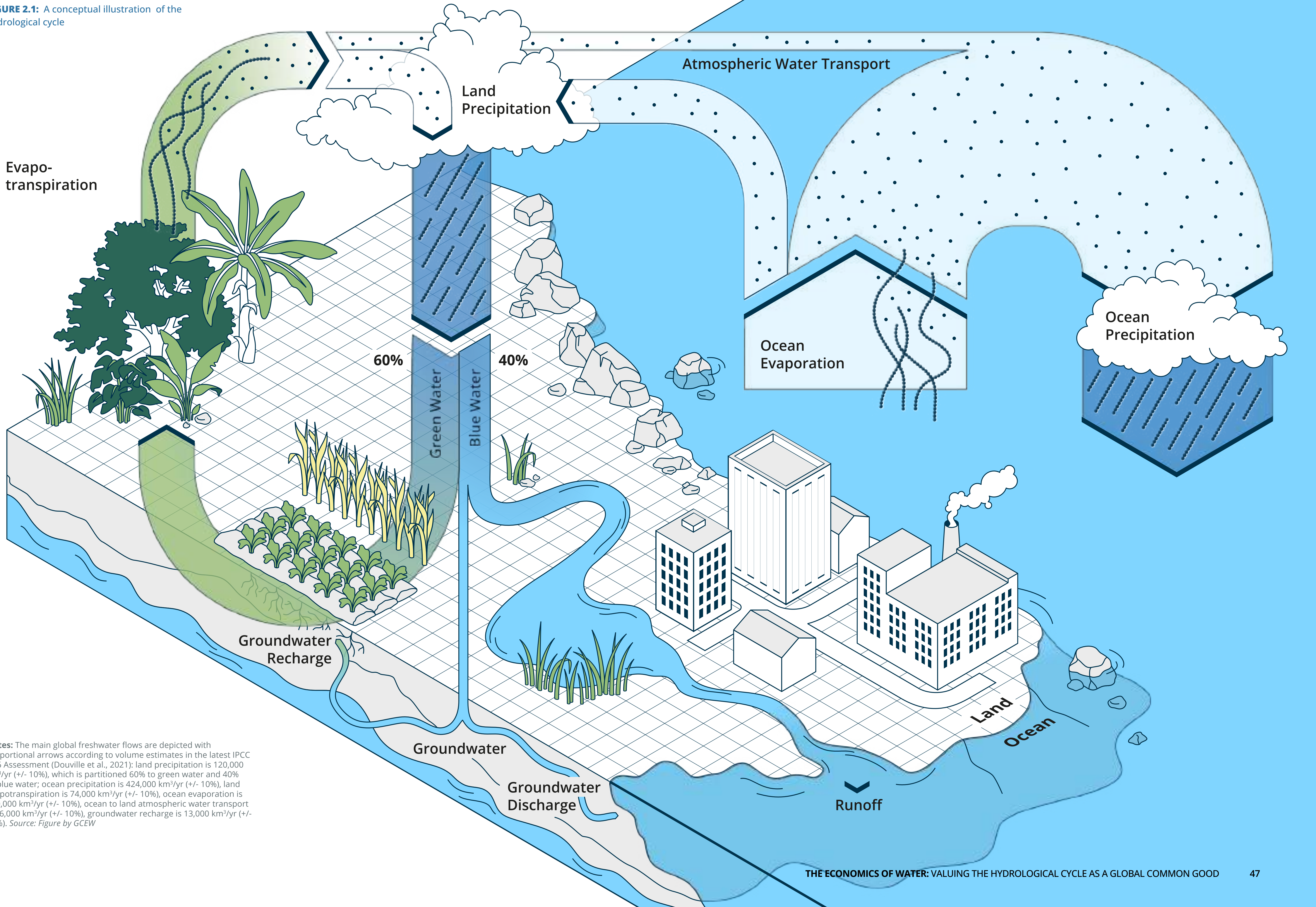
The impacts of poor water quality on health, ecosystem integrity and economic sectors are significant but not well known in aggregate. Moderately polluted rivers (using biological oxygen demand as proxy) can reduce downstream economic growth by 1.4%; heavily polluted rivers have an even higher impact of 2% economic growth reduction downstream; with the highest impacts estimated in middle income countries (Russ, Zaveri, Desbureaux, Damania, & Rodella, 2022).

Climate change is highly likely to put additional pressure on the quality of water resources and freshwater ecosystems. Trade-offs between environmental, societal, and economic objectives to meet water quality objectives will intensify (Wang et al., 2024). Typically, addressing diffuse pollution from agriculture will require considering trade-offs between food security, biodiversity, and climate adaptation and mitigation.

Siloed legislative spheres governing pollutants limit the toolbox of water regulators and the effectiveness of water pollution management. Current environmental water quality standards may no longer fit for purpose, for example in factoring in the impact of chemical mixtures and low doses of substances (Kortenkamp, et al., 2019). Innovative policy responses are burgeoning. Water quality regulation based on effects, rather than on specific substances, is being pioneered by the California State Water Board to guarantee the safety of recycled wastewater (SCCRWP, 2014). New and improved data, as well as advanced water quality monitoring methods, are crucial for understanding and addressing water quality-related risks.

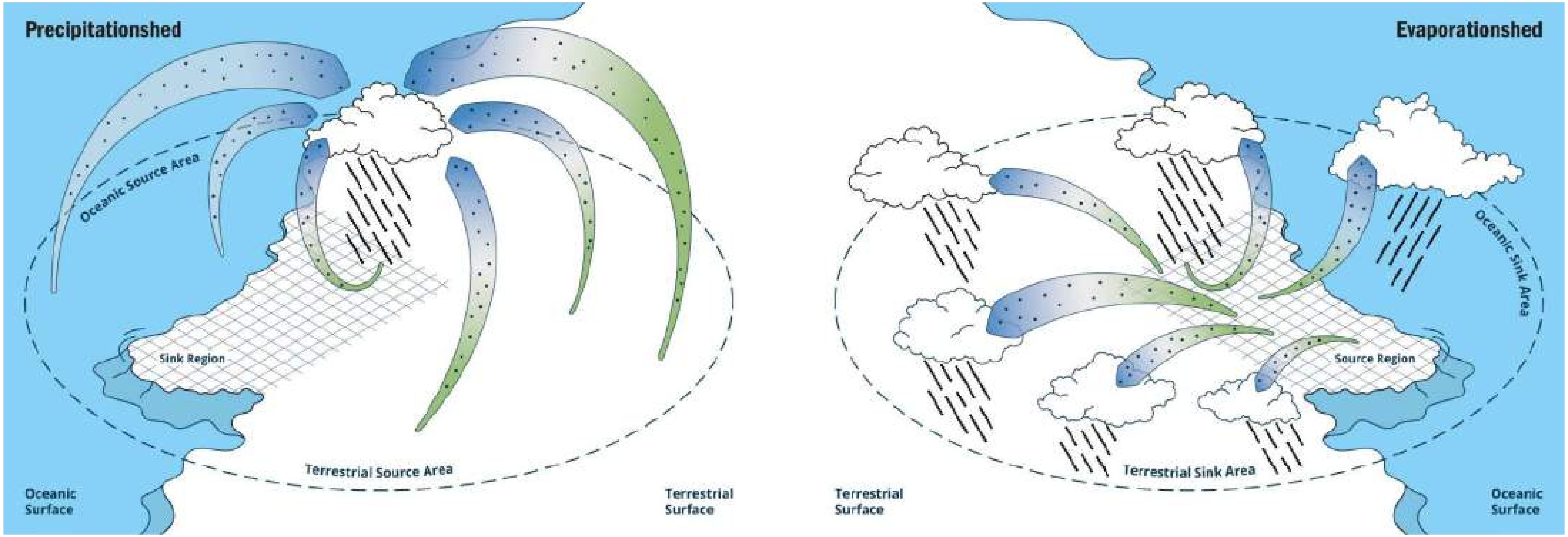
Justice should drive policy responses. For instance, the Polluter Pays principle makes polluting activities costly. As an illustration of an innovative application of the Polluter Pays principle, the European Commission is looking to transfer some of the cost of water treatment to the chemical and cosmetics industry through an extended producer responsibility scheme, reflecting their share in the pollution of water streams (European Commission, 2022).

FIGURE 2.1: A conceptual illustration of the hydrological cycle



Notes: The main global freshwater flows are depicted with proportional arrows according to volume estimates in the latest IPCC AR6 Assessment (Douville et al., 2021): land precipitation is 120,000 km^3/yr (+/- 10%), which is partitioned 60% to green water and 40% to blue water; ocean precipitation is 424,000 km^3/yr (+/- 10%), land evapotranspiration is 74,000 km^3/yr (+/- 10%), ocean evaporation is 470,000 km^3/yr (+/- 10%), ocean to land atmospheric water transport is 46,000 km^3/yr (+/- 10%), groundwater recharge is 13,000 km^3/yr (+/- 10%). *Source: Figure by GCEW*

FIGURE 2.2: Precipitationsheds and evaporationsheds



Notes: Conceptualisation of precipiationsheds and evaporationsheds, where precipitation in the sink region originates from both terrestrial and oceanic sources of evaporation, likewise, evaporation in the source region ends up in both terrestrial and oceanic sink regions as precipitation. Source: Figure by GCEW, Aadapted from Keys et al., 2012

stored in lakes, behind dams, below the water table in aquifers, and in ice, glaciers and snow. Blue water flows form runoff in rivers and sub-surface recharge of water tables and groundwater. Similarly, green water stocks are moisture in the root zone of soils and the water held in plants, while green water flows are vapour released as transpiration and evaporation. Blue and green water stocks and flows are interconnected: river water (blue flow) pumped from a reservoir (blue stock) to an irrigated field creates soil moisture (green stock), which turns into evaporation from the ground and transpiration from crops (both green flows).

Blue water is the basis for all aquatic ecosystems, including wetlands, and is available to humans as an extractable resource. Green water, which is available to plants, supports all terrestrial ecosystems and rainfed agriculture. On global and annual scales, approximately 60% of the precipitation that falls on land goes to green water and 40% to blue water, meaning green water constitutes the majority of freshwater on land (Douville et al., 2021).

Blue water can become "grey" if it is polluted. Increasing water pollution means that a growing share of available water resources is unfit for human use and has a significant detrimental impact on freshwater ecosystem health, reducing the ability of these ecosystems to generate ecosystem services (Box 2.1). Poor water quality is a major challenge in the Anthropocene, negatively impacting economic growth, human potential, and reducing food production (Damania et al. 2019).

Blue and green water both evaporate from bodies of surface water (blue), soil and vegetation (green), while green water also transpires from plants as a product of photosynthesis. *Evapotranspiration* refers to combined evaporation and transpiration. Rising temperatures increase both the atmosphere's water demand and its capacity to hold water. Water supplies are thus connected to Earth's energy balance: land and oceans respond to global warming by evaporating more water. Moreover, as water traps heat, more atmospheric water vapour leads to more warming and more evaporation.

The continuous exchange of moisture between the land and the ocean via atmospheric water transport is analogous to blue water flowing in streams over land according to topography, though atmospheric water flows according to wind patterns and pressure gradients. And like blue water ultimately discharges into a lake or ocean, atmospheric moisture ultimately falls on the land or ocean surface as precipitation.

The spatial extent of a given area's precipitation source area (where does the rain come from?) and evapotranspiration sink area (where is the green flow exported to, contributing to new rainfall?) can be delineated like watersheds on land. A *precipitation*shed includes all the ocean and land areas whose evapotranspiration contributes to an area's precipitation, whereas an *evaporation*shed includes all the ocean and land areas that receive precipitation from an area's evapotranspiration (Figure 2.2).

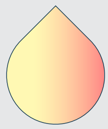
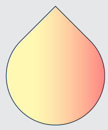
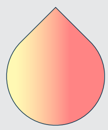
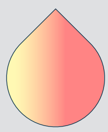
Terrestrial moisture recycling (TMR) describes moisture originating over land that contributes to precipitation also over land, (i.e., land-to-land rainfall, generated on land, transported downwind, and falling on land). Moisture originating in an area that reprecipitates in the same area is called internal moisture recycling (i.e., the source and sink regions are the same). When that area falls within the same country, it is domestic moisture recycling. These atmospheric moisture flows can be simulated by moisture-transport models that track precipitable moisture at the grid scale from its source region as evaporation or evapotranspiration to its sink region as precipitation (Tuinenburg & Staal, 2020; van der Ent et al., 2014).

Though green water flows from land represent a local and immediate water loss to the air, much of it eventually returns to land somewhere as part of the terrestrial water cycle. For decades, general circulation models estimated that 40-60% of terrestrial precipitation is sourced from land, with the remainder coming from ocean sources (Douville et al., 2021; van der Ent et al., 2010). More recent moisture tracking research narrows that estimate to approximately 45% land sources and 55% ocean sources (De Petrillo et al., 2024). Therefore, nearly half of terrestrial rainfall is sourced from land, meaning green water flows are just as critical as ocean evaporation for sustaining precipitation (the source of all freshwater). Green water must therefore be managed in a way that acknowledges the feedback between climate change, land-cover change, and precipitation. Ecosystems whose evapotranspiration is the source of rain at regional scales – especially rainforests (Avissar & Werth, 2005; Werth & Avissar, 2002) and wetlands (Ramsar Convention on Wetlands, 2018) – should be conserved, restored, and sustainably used.

Identifying freshwater boundaries

Due to the fundamental role of freshwater in the Earth system, the global freshwater cycle is included as one of nine planetary boundaries (PB). The concept of planetary boundaries is one of the analytical frameworks used by Earth-system scientists to define a safe operating space for humankind (Richardson et al., 2023; Rockström et al., 2009; Steffen et al., 2015). Recognising that adherence to the biophysical limits of the global freshwater cycle does not necessarily achieve water justice; freshwater is also defined by the Earth Commission in terms of safe and just Earth-system boundaries (ESB) (Rockström et al., 2023; Gupta et al. 2024; Stewart-Koster et al., 2023). The Earth-system boundaries framework includes standards to govern the quality of water; these standards have been violated in many parts of the world (Gupta et al., 2023). Both frameworks express freshwater boundaries in terms of blue and green water,

TABLE 2.1: Freshwater boundaries as depicted by the planetary and earth system boundary frameworks

Freshwater system	Boundary definiton	Safe level	Status
Blue water	**PB:** Percentage land area globally with stream flow deviating from pre-industrial variability (dry/wet) defined by 5th/95th percentile at 0.5° grid level	<10.2% global land area	
	ESB: Surface water flows; collapse of aquatic ecosystems	<20% monthly water flow alteration on 100% of land area	
	ESB: Collapse of groundwater-dependent ecosystems	Average drawdown does not exceed average annual recharge	
Green water	**PB:** Percentage land area globally with soil moisture deviating from pre-indust rial variability (dry/wet) defined by 5th/95th percentile at 0.5° grid level	<11.1% global land area	

Notes: PB = planetary boundary, ESB = Earth system boundary. The status column indicates transgression levels, where yellow indicates rising risk, and red indicates transgressed. *Source: Richardson et al. 2023 (for PB); Stewart-Koster et al., 2023 (for ESB)* using streamflow (blue), soil moisture (green), and groundwater recharge (blue) as indicator variables. Their safe limits are quantified with ecosystem functioning in mind, considering boundary transgression in terms of wet and dry limits. This aligns with thinking in *Turning the Tide* (Mazzucato et al., 2023) and *The What, Why and How of the World Water Crisis* (GCEW, 2023), recognising that water impacts on societies and the economy generally stem from extreme events causing too much, = too little or too dirty water.

The Earth-system boundary framework aims to express safe and just dimensions of freshwater variables in the same unit, and includes only blue water variables (i.e., streamflow and groundwater recharge) in its first phase due to the challenge of quantifying green water in the justice dimension. Across both frameworks and according to all freshwater boundary control variables, freshwater limits are currently transgressed globally (Table 2.1) (Stewart-Koster et al., 2023; Wang-Erlandsson et al., 2022; Porkka et al., 2024; Richardson et al., 2023). The Earth-system boundaries framework includes standards to govern the quality of water; these standards have been violated in many parts of the world (Gupta et al., 2023).

According to the freshwater planetary boundary definition, Figure 2.3 shows land areas that have major and minor wet or dry deviations in streamflow and soil moisture compared to baseline conditions. Every continent and all major basins experience either too much or too little blue or green water. The significant changes in soil moisture are mostly tied to rising temperatures. Boreal zones are experiencing major wet deviations in soil moisture due to melting permafrost and ice, while the central Africa/Sahel region is experiencing major dry deviations in soil moisture due to extreme heat drying the soils. The significant changes in streamflow are mostly tied to human water use, dominated by major dry deviations in streamflow around the world. Instances of wet deviations in streamflow are mainly due to accelerated melting of permafrost and ice.

The degree and extent of freshwater transgressions is particularly worrying, as the other planetary boundaries that influence and interact with freshwater – climate change, biodiversity, nutrient flows, and land-system change – are all breached too (Richardson et al., 2023). Earth is losing the ability to keep environmental and water conditions stable and conducive for human development.

Blue and green water both need to return to a safe operating place within planetary boundaries, with the necessary transformations to occur in a just operating space for Earth-system boundaries. Transgression of global freshwater boundaries alone is not evidence of a global water crisis. However, it indicates that the Earth system is losing resilience and that we are at increasing risk from an intensified and therefore less stable water cycle.

The stage for a global water crisis

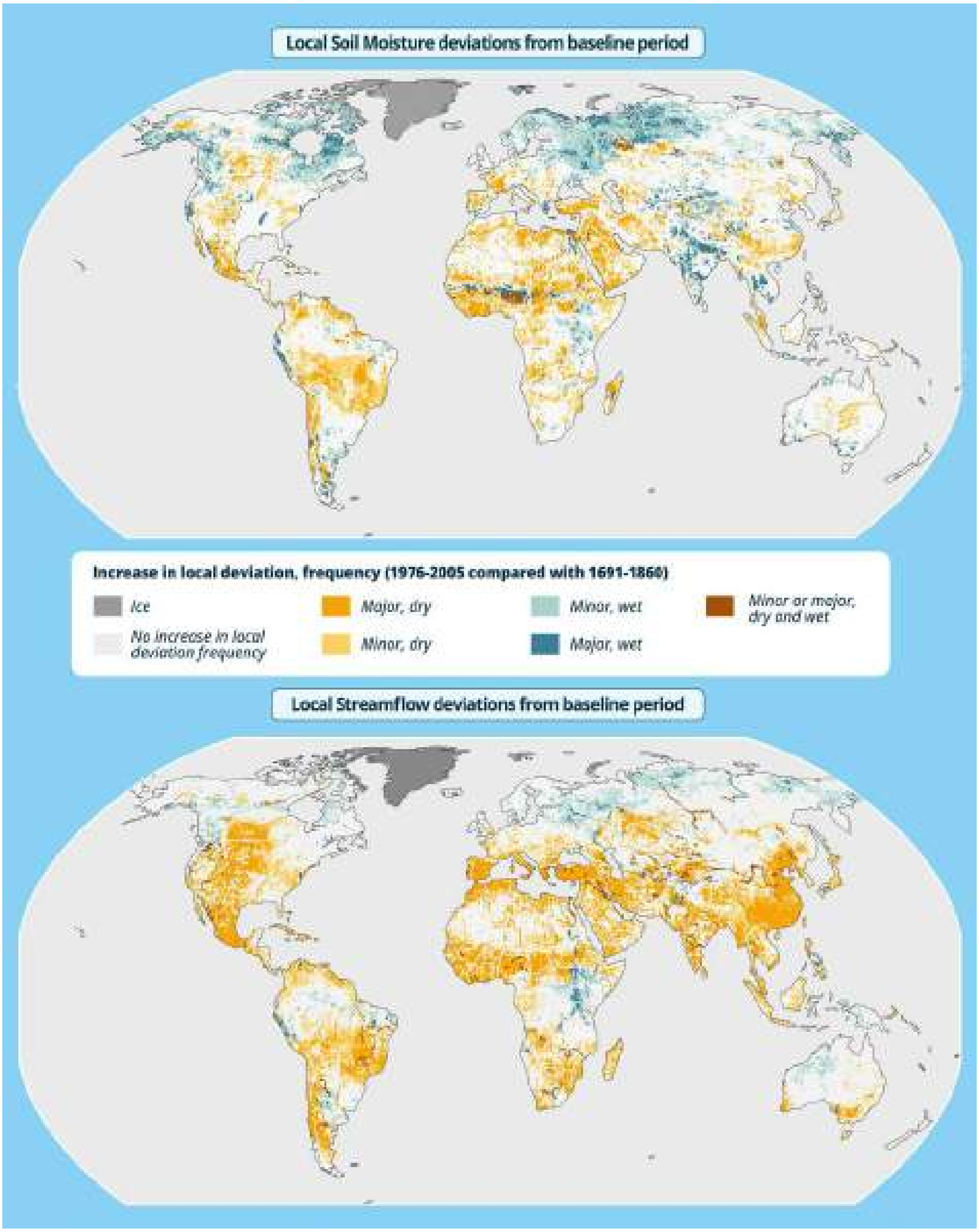
We live in a world of both more frequent and extreme water-related disturbances and of life-supporting systems losing water resilience. We feel the impact on the hydrological cycle and its interactions with atmospheric dynamics, with increasing frequency and severity of droughts and floods around the world. Through climate and land-use change, and unsustainable water use, human-made pressures are pushing the global hydrological cycle out of balance.

While we are breaching boundaries at the global level, regional and local scales already face multiple crises in terms of water quantity and quality. Some 1.4 billion people live in so-called closed river basins, where demand exceeds blue water supply, and there is no longer enough water to meet social and environmental needs (Falkenmark & Molden, 2008; Molle et al., 2010).

Each degree of global warming amplifies projected water availability changes and water-related risks. The last Intergovernmental Panel on Climate Change (IPCC) Report (AR6, Chapter 4) reveals the stark reality in terms people suffering under an intensified global hydrological cycle (Caretta et al., 2022):

- 4 billion people are estimated to experience severe water scarcity for at least some part of the year.
- 3-4 billion additional people are projected to be exposed to physical water scarcity at 2-4°C of global warming, respectively.
- 500 million people live in areas now wetter than normal and about 163 million live in areas now drier than normal (i.e., where long-term average precipitation is high or low, respectively).

FIGURE 2.3: Status of the freshwater planetary boundary variables



Notes: Statistically significant increases and decreases in dry and wet local deviation frequency for streamflow (top panel) and soil moisture (bottom panel). Changes in the frequency of local deviations are computed by comparing ensemble median frequency of local deviations (1976-2005) against a pre-industrial reference period. The changes are classified on the legend as (1) minor changes, wet or dry, (2) major changes, wet or dry, and (3) changes at a location where both wet and dry changes occurred, irrespective of minor or major. *Source: Figure by PIK, data from Porkka et al. (2024).*

- 709 million people live in regions with higher precipitation intensity, whereas 86 million live in areas with lower precipitation intensity (i.e., where annual, maximum, one-day precipitation has increased or decreased, respectively, since the 1950s).

Water scarcity, shortage, and stress

Water *scarcity* describes a lack of water regardless of the reason, though usually connected to physical and natural limitations, as in arid regions and during prolonged drought. Aridity indices, which reflect the climatic degree of dryness of an area, are simple and effective indicators of physical water scarcity. For example, the ratio of average precipitation divided by potential evapotranspiration (P/PET) indicates regions with higher atmospheric demand for water than is available from precipitation, classified as index values of <1. Almost 40% of global land area is under hyper-arid to semi-arid conditions, classified as index values of <0.5 (Figure 2.8d). These areas are prone to physical water scarcity regardless of demand or use efficiency.

In contrast, water *shortage* refers to consumption-driven physical shortfall as assessed against principal water requirements, whereas water *stress* is gauged by how much of the available freshwater supply is needed to meet demand in a period, and can be connected to accessibility problems (e.g. UN Water, 2024). The Falkenmark Index (FI) introduced in 1989 (Falkenmark, 1989) measures blue water stress based on the number of people competing for a unit of flow (i.e., water crowding), showing per-capita availability. In its original form the FI blue water stress thresholds focus on basic human water needs, where available blue water equates to a country's total available annual runoff, less the 30% allocated for environmental flows that sustain aquatic ecosystem functioning. Here, we adapt the FI for water stress to a broader blue water availability index (BWAI), with thresholds for different levels of water scarcity reflecting increasing blue water sufficiency, and perform the analysis at both country and grid scales. Figure 2.6 provides an updated BWAI assessment at local (grid) scale, utilising the most recent ensemble of global hydrological modelling outputs over the historical period 2010-2019 (see methods and country scale results in Appendix 2.1).

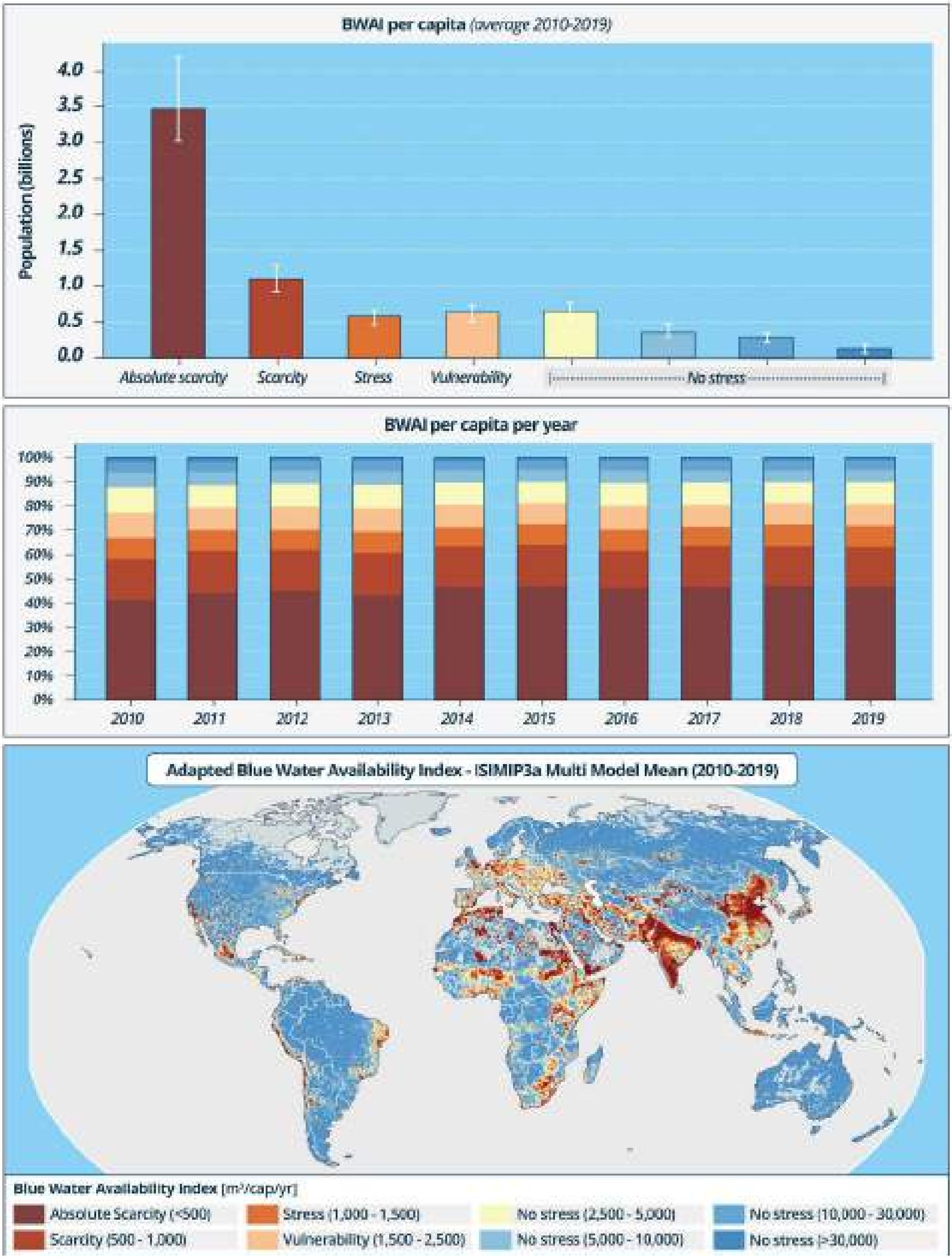
Despite natural variability over time, the trend over the last decade is clear: approximately 70% of the world population (over 5 billion people) live under local blue water stress or worse, with about 4.5 billion people under blue water scarce conditions – and these numbers are only rising due to increasing population. If available blue water is assumed to be accessible equally to the entire population at country scale, 50% of the world population would still be living under blue water stress or worse, with about 1.5 billion people still under scarce conditions (Appendix 2.1). The grid scale BWAI reflects availability according to local runoff topology (e.g. Vörösmarty et al., 2000) assuming no water sharing or transfers, and will therefore reflect high water crowding in populated areas, whereas the country scale BWAI assessment spreads this demand to a wider area.

Given that the water scarcity indices are based on per capita water availability, there are discrepancies between the geographical assessment of aridity (Figure 2.8d) and (human) blue water stress (Figure 2.4). For example, sparsely populated regions of northern Africa, though arid, are classified as "not stressed", while densely populated parts of northern Europe, though humid, are classified as "scarce" or "stressed", which comes down to how many people crowd the resource.

Assessing freshwater availability only in terms of blue water misses 60% of the total freshwater resource (green water). In terms of human water requirements, green water mainly relates to rainfed agriculture and is defined as the soil moisture available for productive moisture flow (evapotranspiration) from agricultural land. Considering water requirements for food production, it is estimated that a total of 1,300 m^3/person/year of evapotranspiration from blue and green sources is needed to produce a standard diet (Rockström et al., 2009). Of this, a minimum of 600 m^3/p/y of productive transpiration (green water) is needed.

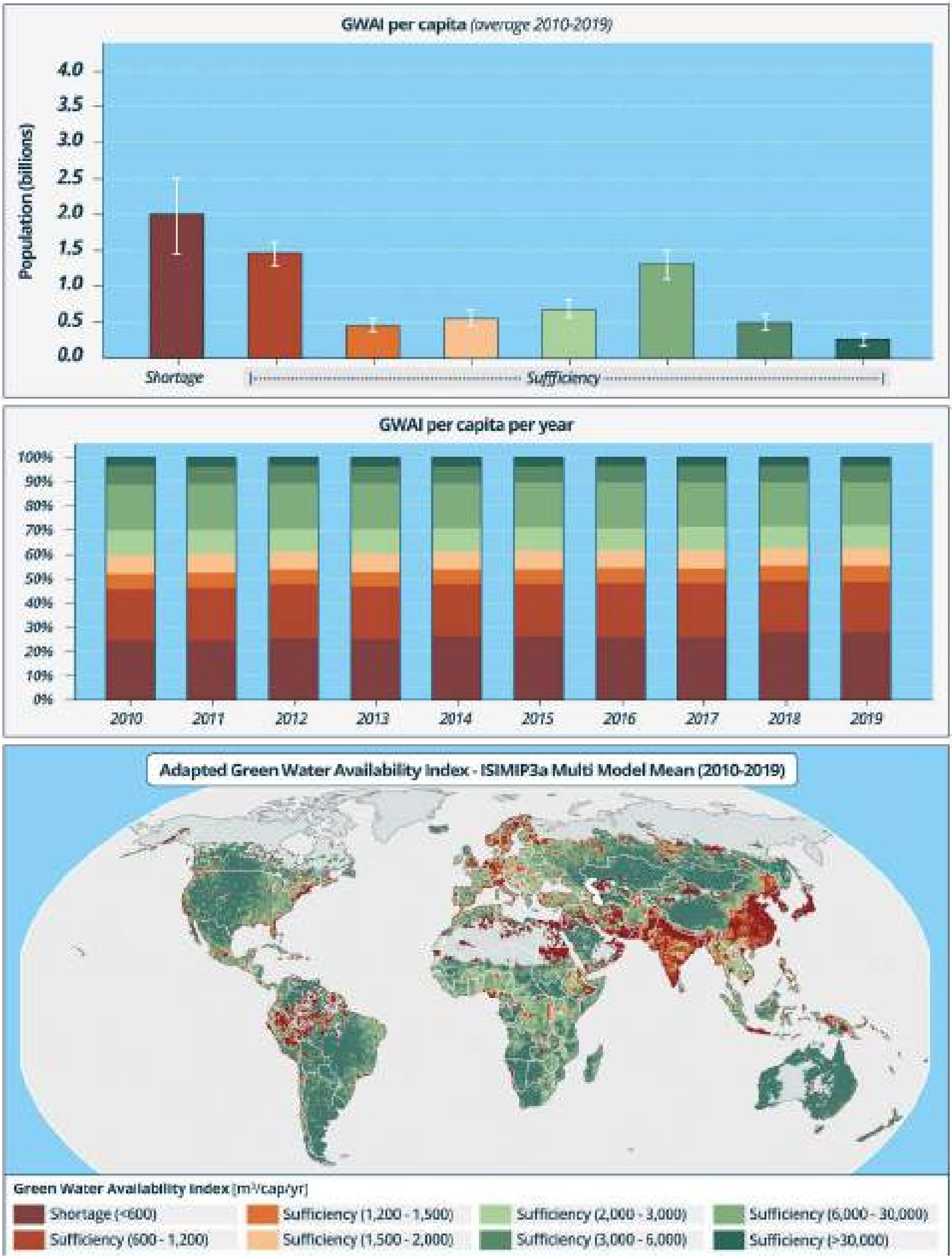
A green water availability index (GWAI) threshold can therefore be set at 600 m^3/p/y evapotranspiration from rainfed agricultural land. Below this threshold corresponds to absolute green water shortage, at the threshold there is – theoretically – sufficient green water (assuming 100% transpiration efficiency), and above this threshold are levels of green water sufficiency given decreasing transpiration efficiency. In other words, when green water per capita is less abundant, producing a standard diet needs higher transpiration efficiency.

FIGURE 2.4: Blue water availability index



Notes: Blue water availability index (BWAI) in m³/p/y – absolute scarcity <500; scarcity 500–1,000; stress 1,000–1,500; vulnerable 1,500–2,500 – or into "no stress" classes reflecting increasing blue water sufficiency: 2,500–5,000; 5,000–10,000; 10,000–30,000 and >30,000. The global totals and percentages of people living under these blue water availability classes are shown in the top panel, with the spread among models on the mean over 2010-19 (left) and the multi-model mean over time (right). The bottom panel maps the BWAI at 0.5° grid scale averaged over 2010-19. Analysis is performed with output from the ISIMIP3a ensemble of global hydrological models (Frieler et al., 2024).

FIGURE 2.5: Green water availability index



Notes: Green water availability index (GWAI) based on productive green water flow (ET) from rainfed agricultural lands and permanent pasture lands (e.g. excluding forested/naturally vegetated lands), averaged over 2010-19, in m3/p/y. Green water shortage is <600 and green water sufficiency is >600, assuming various levels of transpiration efficiency that would be needed to produce an adequate diet, where 600 = 100% transpiration efficiency, 1,200 = 50%, 1,500 = 40%, 2,000 = 30%, 3,000 = 20%, 6,000 = 10%, and 30,000 = 2%. The global totals and percentages of people living under these GWAI classes are shown in the top panel (over the period 2010-2019), with the spread among models on the mean over 2010-19 for each GWAI range (left) and the multi-model mean over time (right). Analysis is performed with output from the ISIMIP3a ensemble of global hydrological models (Frieler et al.; 2024).

Figure 2.5 provides an updated green water availability assessment applying the GWAI at local (grid) scale (see methods and country scale results in Appendix 2.1). Approximately 2 billion people live under local green water shortage conditions, where green water resources are not sufficient to support adequate diets. Over 4.5 billion people live in areas where a transpiration efficiency over 40% would be required to produce adequate diets. Most of these people are likely living under green water shortage, given the global average transpiration efficiency on agricultural lands is 45% (Rockström et al., 2009). The remaining almost 3 billion people live in areas with green water sufficiency for producing adequate diets.

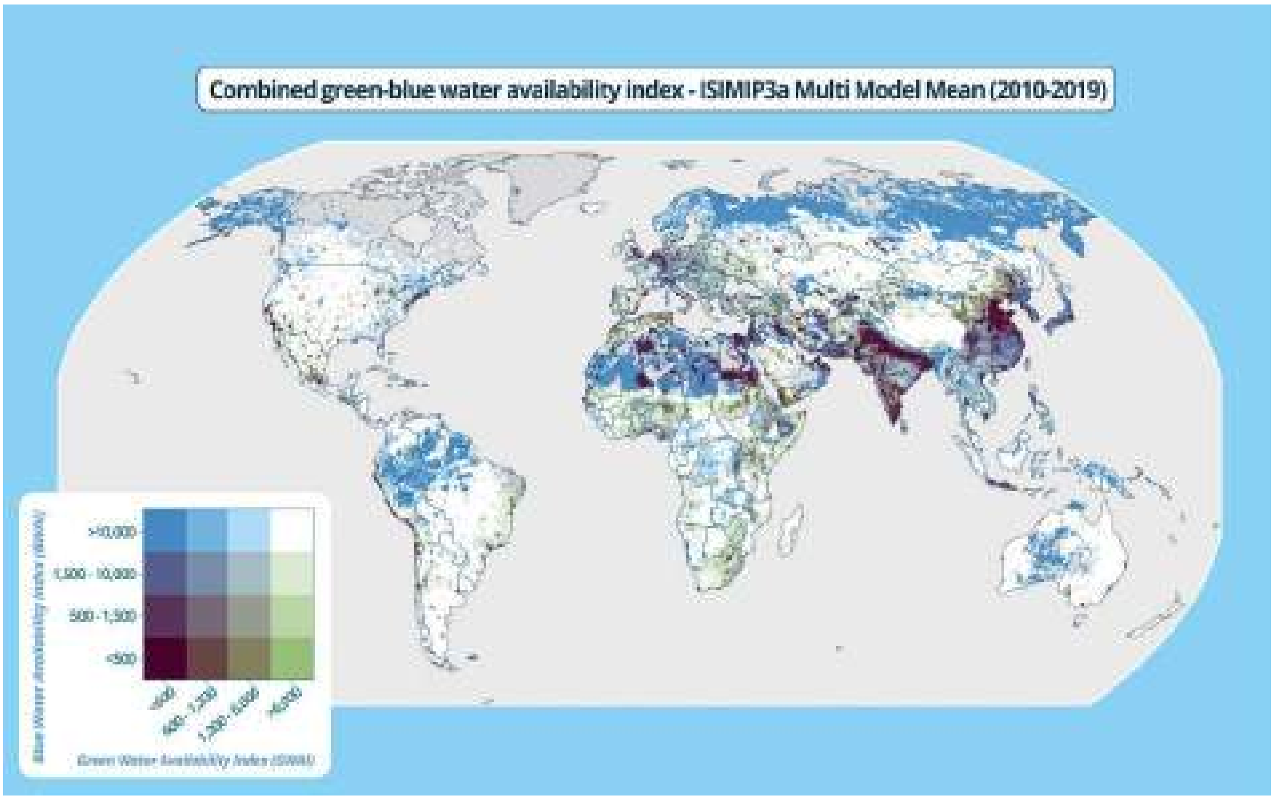
These green and blue water indicators can be combined into a green-blue water availability index (GBWAI) to compare the sum of green and blue water availability, allowing assessment across all dimensions of blue and green water shortage and sufficiency (Rockström et al., 2009). Figure 2.6 provides an updated green-blue water availability assessment at local (grid) scale (see methods and country scales in Appendix 2.1).

In principle, much of the world has sufficient water resources when considering combined blue and green water availability. Many regions are lifted out of absolute water scarcity based on blue water alone when adding green water to the equation, for example, in parts of Africa, China, the Middle East, and Europe (Figure 2.6, see areas in green). This underpins how critical green water is for rainfed agriculture in some blue-water-scarce regions, and thus the potential to generate adequate diets for their populations through sustainable water management.

Total terrestrial water storage

The total terrestrial water storage, which covers blue water in rivers, lakes, groundwater, snow and ice, and green water stores as soil moisture, is an integrated indicator of water stocks supporting the global economy by supplying water to societies and industry, and providing water for all aquatic and terrestrial ecosystems as well as food and biomass production in rainfed and irrigated production. The water stored in water tables and deeper aquifers enable

FIGURE 2.6: Combined blue and green water availability index



Notes: The map shows the dimension of green-blue water availability at grid scale averaged over 2010-19. In the two-dimensional legend, blue water availability is depicted vertically and green water availability is depicted horizontally. Absolute green and blue water scarcity is indicated with dark purple in the lower left, green water sufficiency under blue water scarcity is green in the lower right, blue water sufficiency under green water shortage is blue in the upper left, and blue and green water sufficiency is white in the upper right. Analysis is performed with output from the ISIMIP3a ensemble of global hydrological models (Frieler et al.; 2024).

people to grow crops in places where rainfall is too limited or unreliable. This groundwater, which provides 49% of water withdrawn for domestic use worldwide and about 43% of all water withdrawn for irrigation (Rodella et al. eds., 2023), is a valuable resource amid climate change, as it does not change seasonally and does not evaporate like surface water during hot spells. But large numbers of aquifers are being rapidly depleted.

China and India rely heavily on groundwater to boost agricultural productivity through irrigation, depleting their stock. In India, the volume of water over-abstracted between 1996 and 2016 is estimated at around 120–200 km^3 (Rodella et al. eds., 2023). Aquifer depletion can lead to land subsidence and salinisation. In China, land around major cities such as Beijing, Shanghai, and Wuhan is subsiding as aquifers are depleted to support agriculture and urban needs (Hasan et al., 2023). In Indonesia, the combination of sea-level rise and sinking land due to aquifer depletion has created severe flood risks (Renaldi, 2023).

Scientists' ability to measure the extent of groundwater depletion, water levels in lakes and rivers, soil moisture and changes to water stored in snow and ice has greatly improved in the last two decades thanks to the Gravity Recovery and Climate Experiment (GRACE) satellite missions, which can measure the total amount of water stored on and below the Earth's surface (Güntner, n.d.).

Observed over time, it is possible to estimate changes in total terrestrial water storage, or how much water is lost or gained from a given region. Importantly, losses and gains are summed per slice of the Earth being measured, so it is also possible they cancel out to some degree. That said, the data from GRACE continues to be critical in understanding regional groundwater depletion, droughts and floods, and how water is distributed around the globe over time (Figure 2.7).

Total terrestrial water storage changes seasonally. In Central Europe, it rises in the winter with higher precipitation and lower evaporation rates, and drops in the summer. In the tropics, levels rise during the rainy or monsoon season and decline during the dry season. The satellites can also "see" the footprints of large floods after the waters have receded. And they can detect whether the soil is still very dry a few centimetres below the surface even if rain dampens the soil after a long drought.

Trends in terrestrial water storage can tell us how climate change, land use, and blue water use (including groundwater abstraction) are affecting overall water supplies. Total terrestrial water storage is therefore a good, integrated, blue and green water metric to identify the trend in freshwater availability, and a good proxy for the state of freshwater resources.

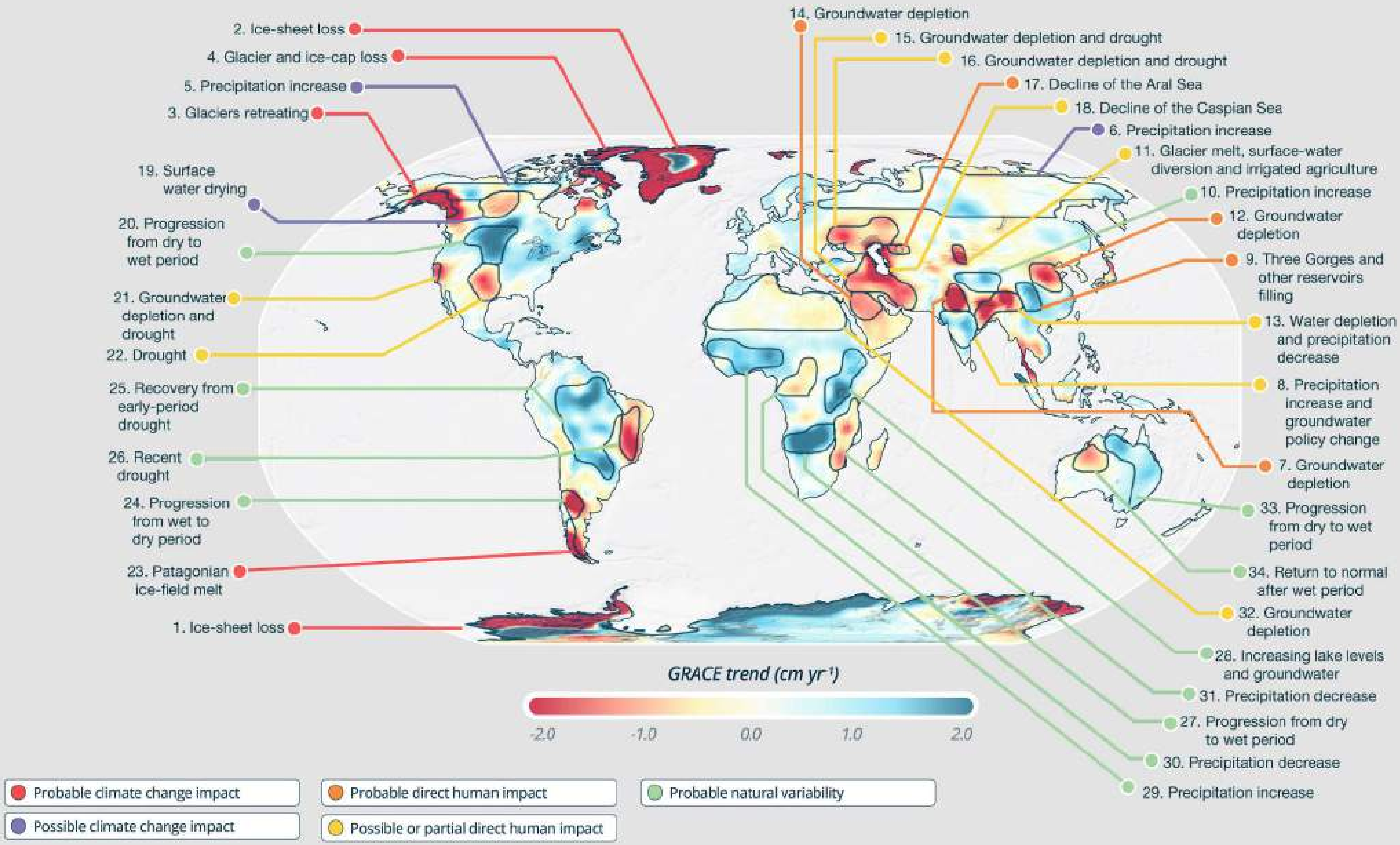
Combined with information about water shortage and physical scarcity indicators, this can help us identify hotspots of particular concern. The biggest terrestrial water storage losses documented to date involve the shrinking Greenland ice sheet and glaciers in the Americas and Asia (Güntner, n.d.). Some areas, such as parts of Central Africa and Southeast Asia, are gaining terrestrial water storage. Figure 2.8 combines terrestrial water storage, groundwater depth, and average monthly aridity to gauge the extent to which areas are exposed to multiple stressors.

A destabilising global water cycle

Blue and green water, and the stability of the hydrological cycle, are being affected by human action changing precipitation patterns through climate and land use change. As the mean global temperature rises, the hydrological cycle intensifies, and mean global precipitation increases. On average, every 1°C of global warming adds 7% moisture-holding capacity to the atmosphere, which adds power to the global hydrological cycle, leading to more extreme events, like intense rainfall, hurricanes and cyclonic storms, and associated storm surges and coastal flooding, affecting billions of people. We have today reached a global mean air surface temperature increase of 1.2°C since pre-industrial levels (Caretta et al., 2022).

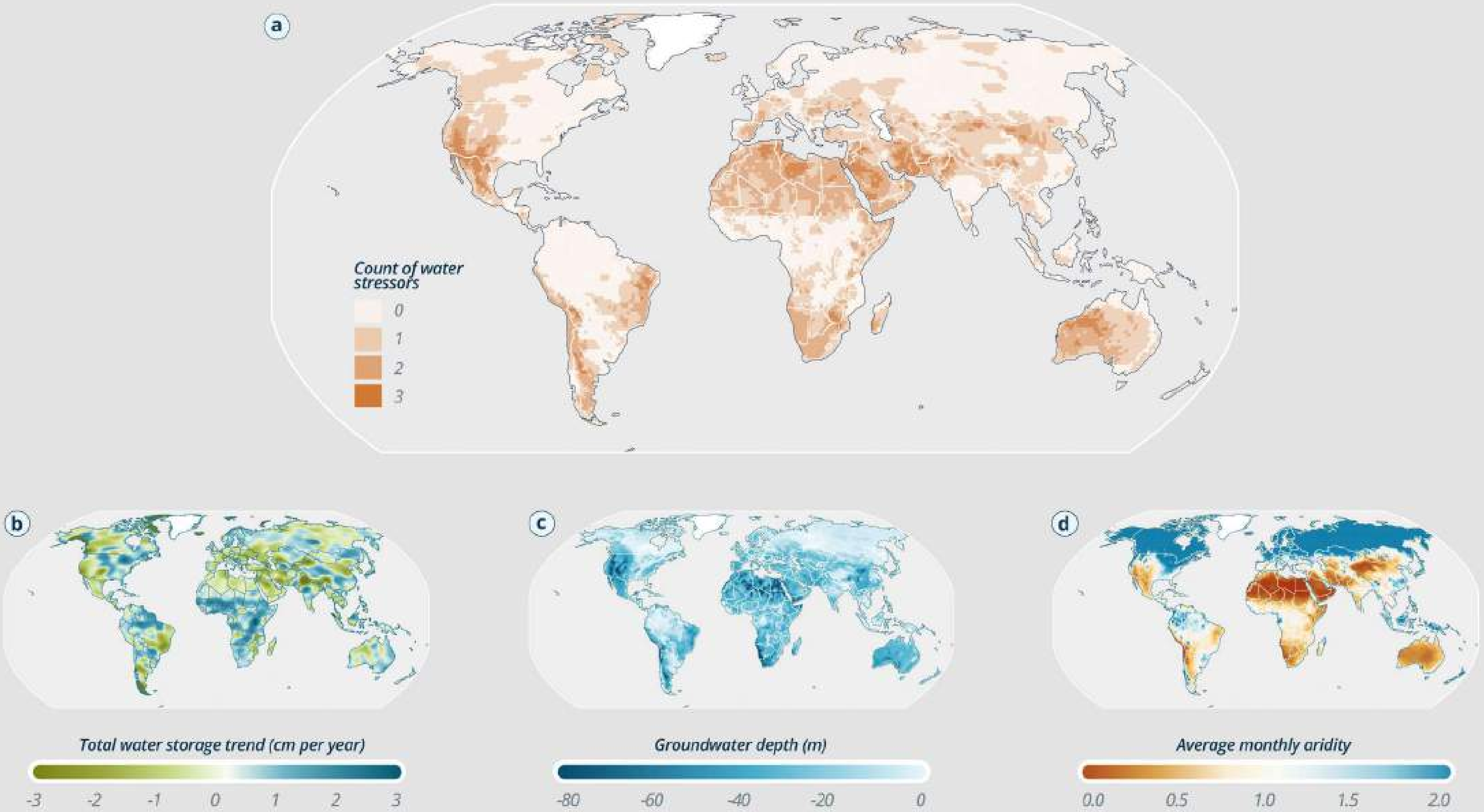
The latest IPCC assessment provides projections of expected changes in global precipitation under different warming scenarios (RCPs) and world development trajectories (Shared Socioeconomic Pathways, (SSP) (Douville et al., 2021). Here, we translate these projections of daily change (mm/day) to annual estimates (km^3/yr) over land areas only (Table 2.2). We find that terrestrial precipitation in the reference period 1995-2014 is almost at 120,000 km^3/yr, a marked increase from previous estimates of 110,000 km^3/yr in earlier decades (e.g. Speidel and Allen, 1982). With continued climate change, terrestrial precipitation could increase over 10% globally from 1995-2014 levels by the end of the century, depending on the SSP climate scenario.

FIGURE 2.7: Annotated map of terrestrial water storage trends



Notes: Trends in total terrestrial water storage (cm/year) obtained based on GRACE observations from April 2002 to March 2016. The cause of the trend in each outlined study region is explained and colour-coded by category. Source: Rodell et al., 2018.

FIGURE 2.8: Uncovering water shortage "hotspots"



Notes: (a) shows how many water stressors a region is exposed to. Colours indicate if a grid cell falls into zero, one, two or three of the following water stress categories: (1) lowest quartile of global total water storage trends distribution; (2) lowest quartile of the global groundwater depth distribution; and (3) lowest quartile of the global aridity distribution. **(b)-(d)** show spatial patterns of the three water-availability metrics: **(b)** linear trends in total water storage during the GRACE satellite record 2003-22 in cm of equivalent water height per year; **(c)** groundwater depth from Fan, Li and Miguez-Macho (2013); **(d)** average monthly aridity between 2003 and 2019 calculated as precipitation divided by potential evapotranspiration. Classification: Hyper-arid <0.05, Arid 0.05-0.20, Semi-arid 0.20-0.50, Dry sub-humid 0.50-0.65, Humid >0.65. All maps are shown at the ~1° equal-area GRACE grid.

TABLE 2.2: Projected change in global terrestrial precipitation, by ssp scenario

[Precip km³/yr]	Reference	Mid-term: 2041 - 2060				
	1995-2014	SSP1-1.9	SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Mean	**117,041**	**123,700**	**123,700**	**123,172**	**123,172**	**124,758**
Error bar [low]	102,089	103,612	104,670	104,141	103,612	104,141
Error bar [high]	136,388	142,203	143,260	143,260	142,731	144,846
[Precip km³/yr]	**Reference**	**Long-term: 2081 - 2100**				
	1995-2014	**SSP1-1.9**	**SSP1-2.6**	**SSP2-4.5**	**SSP3-7.0**	**SSP5-8.5**
Mean	**117,041**	**123,172**	**124,229**	**125,815**	**127,401**	**130,573**
Error bar [low]	102,089	105,198	105,727	105,727	106,256	108,370
Error bar [high]	136,388	141,674	144,846	146,432	148,018	153,304

As the increase in catastrophic hurricanes and torrential rainfall has already shown, a warmer, wetter world comes with increasingly severe water-related disaster risks (Caretta et al., 2022). At the same time, even though precipitation is projected to increase at the global scale, there are large differences between countries and regions. Figure 2.9 shows the percentage change in precipitation under the moderate (SSP) 2-4.5 climate scenario in the long term (2081–2100): Central Africa, India, and China see up to 30% more rainfall, but most of Europe, Central and South America, South Africa, and Australia see decreases of as much as 25%. Land-use change could exacerbate the drying effect by reducing terrestrial moisture recycling.

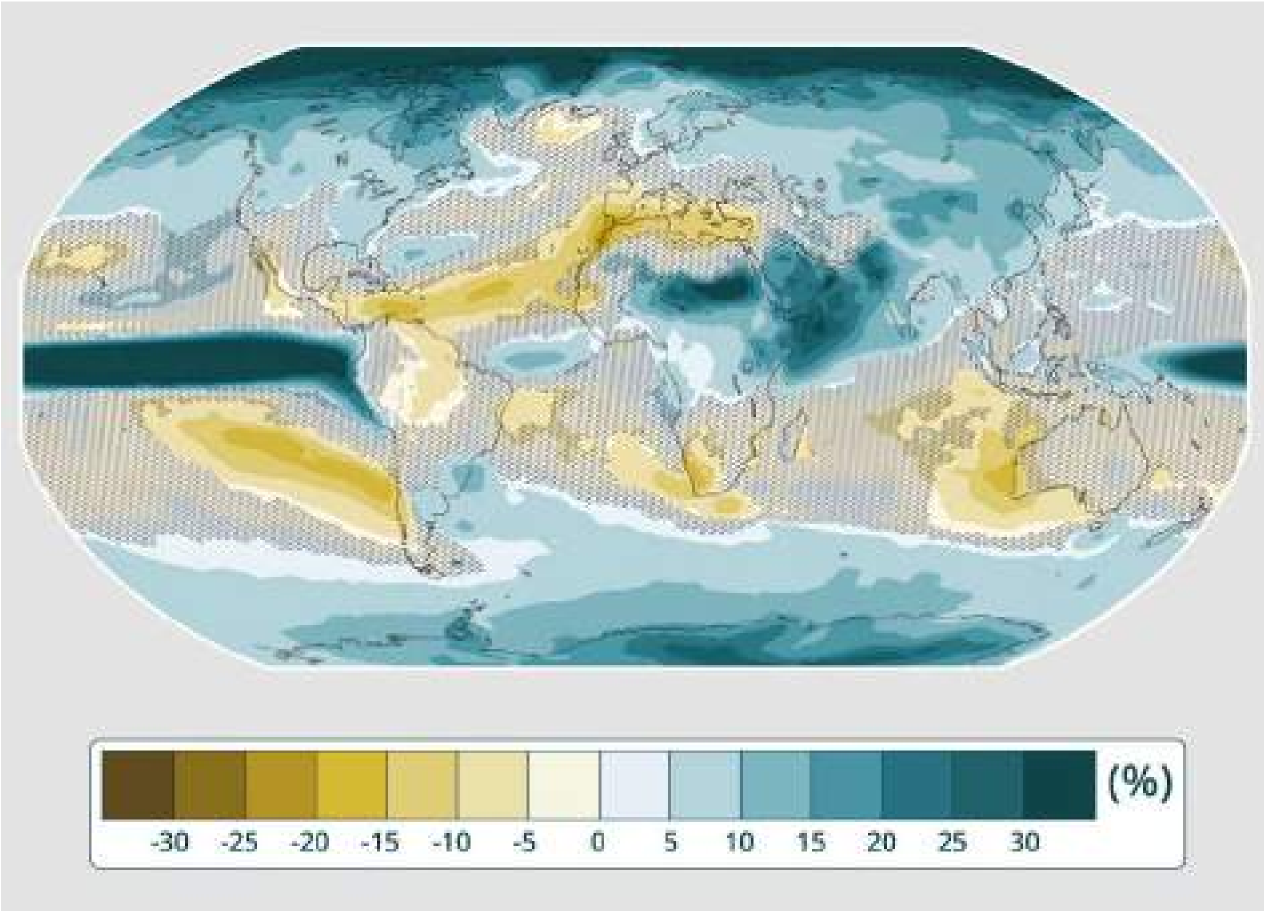
Transboundary green water

Like many river basins and aquifers, atmospheric moisture flows are transboundary resources, carrying water from one country to another, even across continents and oceans. Global atmospheric moisture flows have been mapped and quantified to show how the freshwater cycle connects countries and regions around the planet (Dirmeyer et al., 2009; Tuinenburg et al., 2020).

Figure 2.10 shows terrestrial moisture exchange between countries according to a reconciled country to country flow network (De Petrillo et al., 2024), depicting the striking interconnectedness of countries through atmospheric moisture flows. Land to land moisture connections can be seen across oceans, connecting evaporation in west African countries to rainfall in South American countries, and evaporation in North American countries to precipitation in European countries.

The subcontinental moisture flow dynamics are well illustrated with the case of Brazil, which receives moisture from across the Atlantic Ocean, recycles this rainfall through the Amazon rainforest, which evapotranspires and sends moisture downwind to its neighbouring countries. This makes Brazil a so-called net exporter of terrestrial moisture, as it

FIGURE 2.9: Projected percentage change in mean annual precipitation (SSP2-4.5 2081–2100 relative to 1995–2014)



Notes: Projected percentage change in mean annual precipitation (2081–2100 relative to 1995–2014), ensemble mean over the CMIP6 climate models based on simulations for SSP2-4.5 Source: Tebaldi et al. 2021

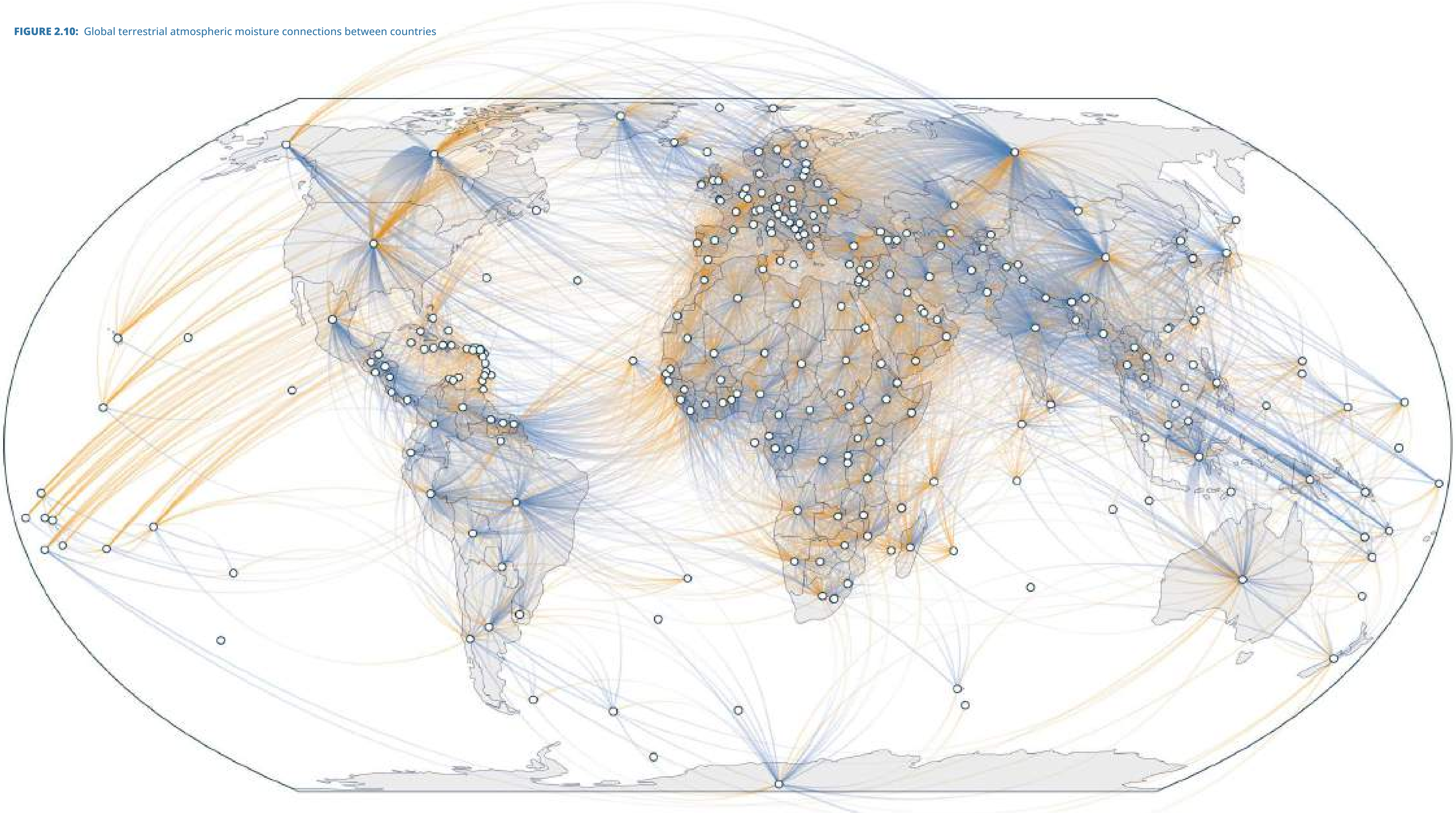
sends more green water flow (ET) to other countries than it receives (Figure 2.11). Overall, South America is a net importer of moisture, primarily from the South Atlantic Ocean, but the continent also has the largest volume of moisture recycling, owing to the moisture-generation and conveyance power of the Amazon rainforest, which creates 36% of its own rainfall (Smith et al., 2023).

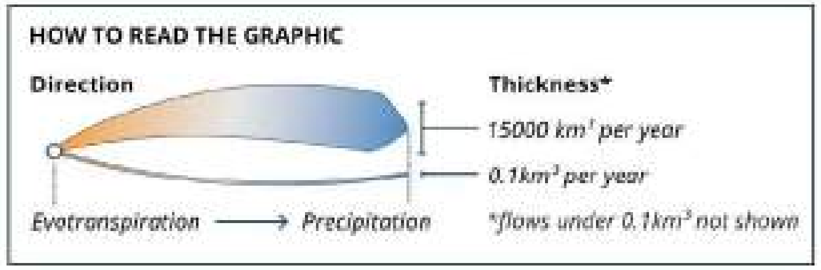
Figure 2.11 shows the degree to which countries are net importers or exporters of land to land moisture flow. Some countries with large, dense tropical forests, such as Brazil and the Democratic Republic of Congo, and/or vast land areas, such as China and Russia, have high rates of domestic moisture recycling (De Petrillo et al., 2024) and thus significant self-interest in protecting those ecosystems. A key takeaway from Figure 2.10, however, is that green water supplies are far more regionally interdependent than realised.

Figure 2.12 shows the atmospheric moisture sink and source regions of seven major river basins around the world (Amazon, Brahmaputra, Colorado, Congo, Danube, Murray, Yenisey). Notably, the atmospheric watersheds, i.e. precipitationsheds and evaporationsheds, of these major river basins extend to regions well beyond the surface area of the basin itself, even reaching across oceans to other continents. Not only does this broaden the concept of transboundary water, but it makes a compelling case for a globally connected freshwater cycle.

This evidence shows that all countries and regions are interconnected and depend on one or several neighbouring areas to secure stable freshwater supplies. Furthermore, intact and biodiverse ecosystems and managed lands which do not adversely impact their hydrological functioning (i.e., green water flux) are critical to preserving terrestrial moisture recycling and securing up to 50% of precipitation on land (globally). Atmospheric moisture flows connect all continents, making freshwater a global common good that needs to be governed as such.

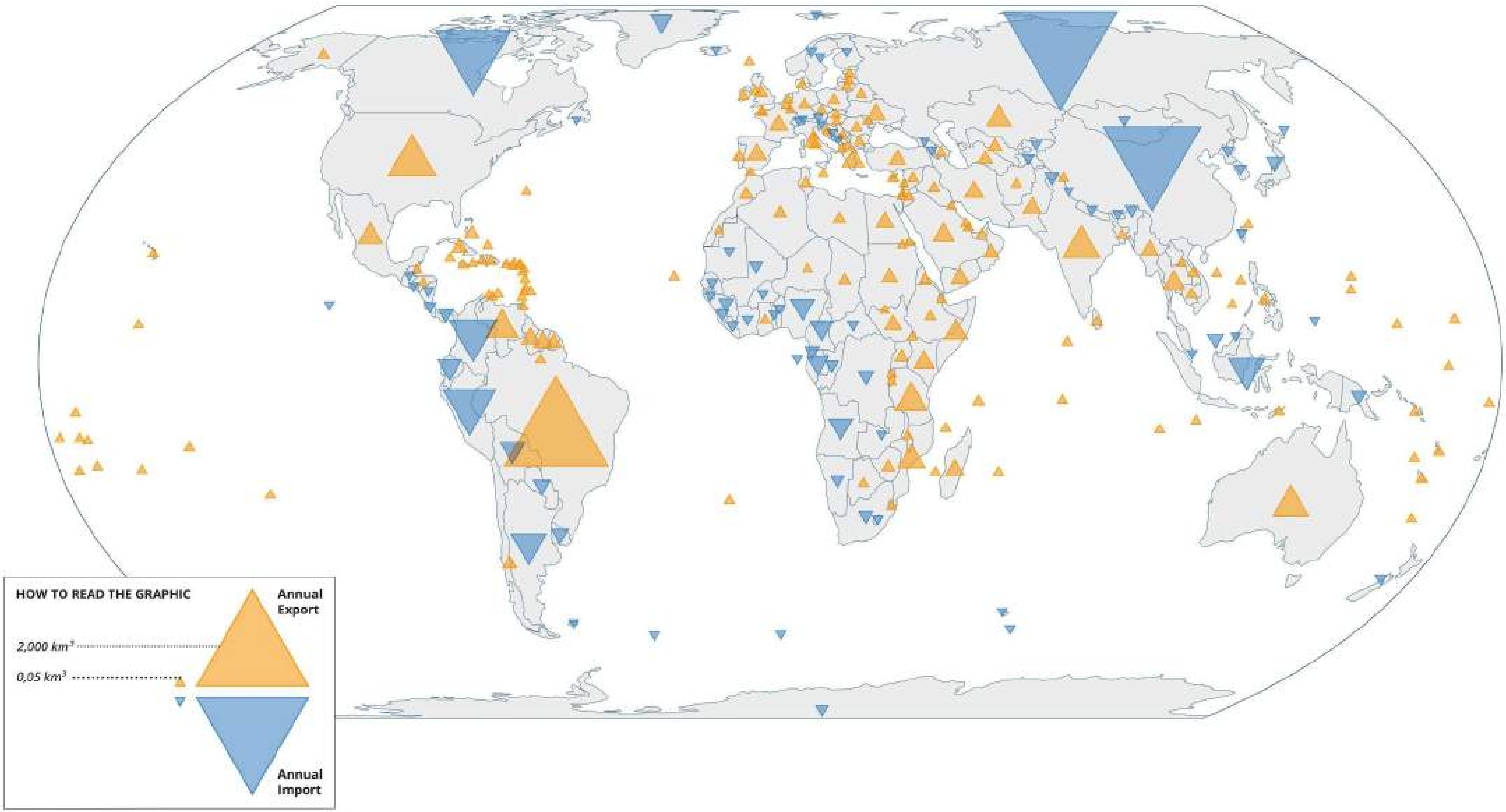
FIGURE 2.10: Global terrestrial atmospheric moisture connections between countries





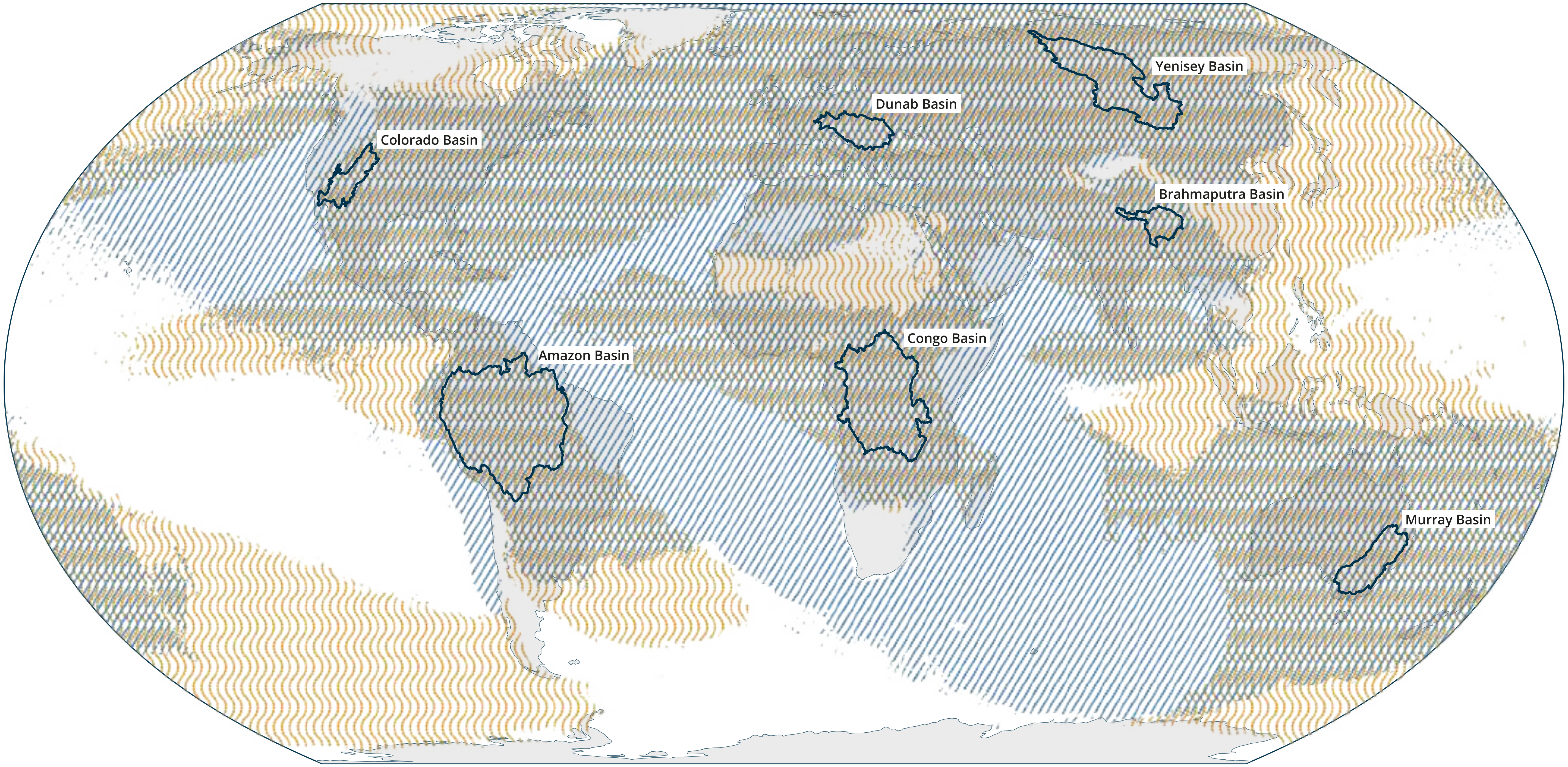
Notes: Average annual terrestrial atmospheric moisture exchange between countries is depicted with flow arrows which begin as evaporation (shown in orange) in the source country and end as precipitation (shown in blue) in the sink country. Each country is represented in the flow network by a white dot at its centroid. Based on average annual flows over the periods 2008-2017. Source: GCEW based on data from De Petrillo et al., 2024.

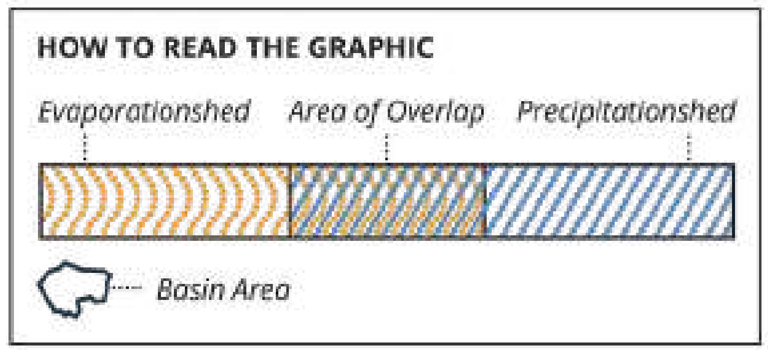
FIGURE 2.11: Countries as net importers or exporters of terrestrial atmospheric moisture



Notes: Countries are depicted as net importers or exporters of terrestrial atmospheric moisture, based on average annual flows over the periods 2008-2017. Source: GCEW based on data from De Petrillo et al., 2024.

FIGURE 2.12: Precipitationsheds and evaporationsheds of major river basins on every continent





Notes: Atmospheric watersheds - precipitationsheds and evaporationsheds- tend to implicate far greater spatial extents than surface watersheds. Displayed are the precipitationsheds (blue) and evaporationsheds (orange) for the Amazon (South America), Congo (Africa), Danube (Europe), Murray-Darling (Australia), Yenisey (Northern Asia), Brahmaputra (Southeast Asia), and Colorado (North America). Here, with just one major river basin per continent considered, nearly the entire globe is implied as receiving or sourcing area of atmospheric moisture from or to at least one of the river basins. Source: GCEW based on data from De Petrillo et al., 2024.

The hydrological cycle as a global common good

It is time to rethink the economics of water to help steer the world away from dangerous over-consumption, profound injustices and dwindling, degraded water, and towards a just and sustainable future where competing priorities of efficiency, equity, and environmental sustainability are managed. The latest scientific assessments point to the need to reframe the hydrological cycle as a global common good.

First, the hydrological cycle links countries and communities. This is well established for blue surface water in rivers and lakes, and the local institutions, property rights and valuation and pricing mechanisms that have evolved over millennia. This is less well understood in the case of groundwater, which is also largely managed as a local issue. Groundwater is more difficult to visualise and monitor, although new satellite technology is making it easier. Even less understood, and thereby absent in economics and policy, is the country and sector inter-connectedness through green water. Recent studies have given us a much better understanding of the green water size and dynamics in the hydrological cycle and especially the share of terrestrial water recycling, which is no longer a local or even a regional issue but part of the overall functioning of the biosphere. And what ultimately regulates the annual cycling of freshwater and the stability of future water supply, i.e., rainfall.

The argument that water action in one part of the world does not benefit or affect countries or communities in other parts of the world is no longer true in the 21st Century due to human caused global environmental change, and advances in scientific understanding. The latest science suggests that, while the local and transboundary dimensions of blue water remain, the regional and global dimensions of green water require further collaborative investigation across all countries and regions.

These local, regional, and global interdependencies will need to be acknowledged, better understood, and managed for the greater common good of current and future generations and the biosphere, based on that:

- Water travels long distances. Atmospheric moisture flows connect communities across borders, continents, and oceans in patterns that shift with the prevailing winds and rarely match the already-complex geography of surface water and aquifers.
- The science of terrestrial moisture recycling helps understand how local actions – typically land-use change – can affect rainfall in other parts of a country or distant regions.

Second, the global hydrological cycle is deeply interlinked with the climate and biodiversity crises. The hydrological cycle is clearly impacted by climate change. Evidence shows that the destabilisation of the hydrological cycle can exacerbate the climate

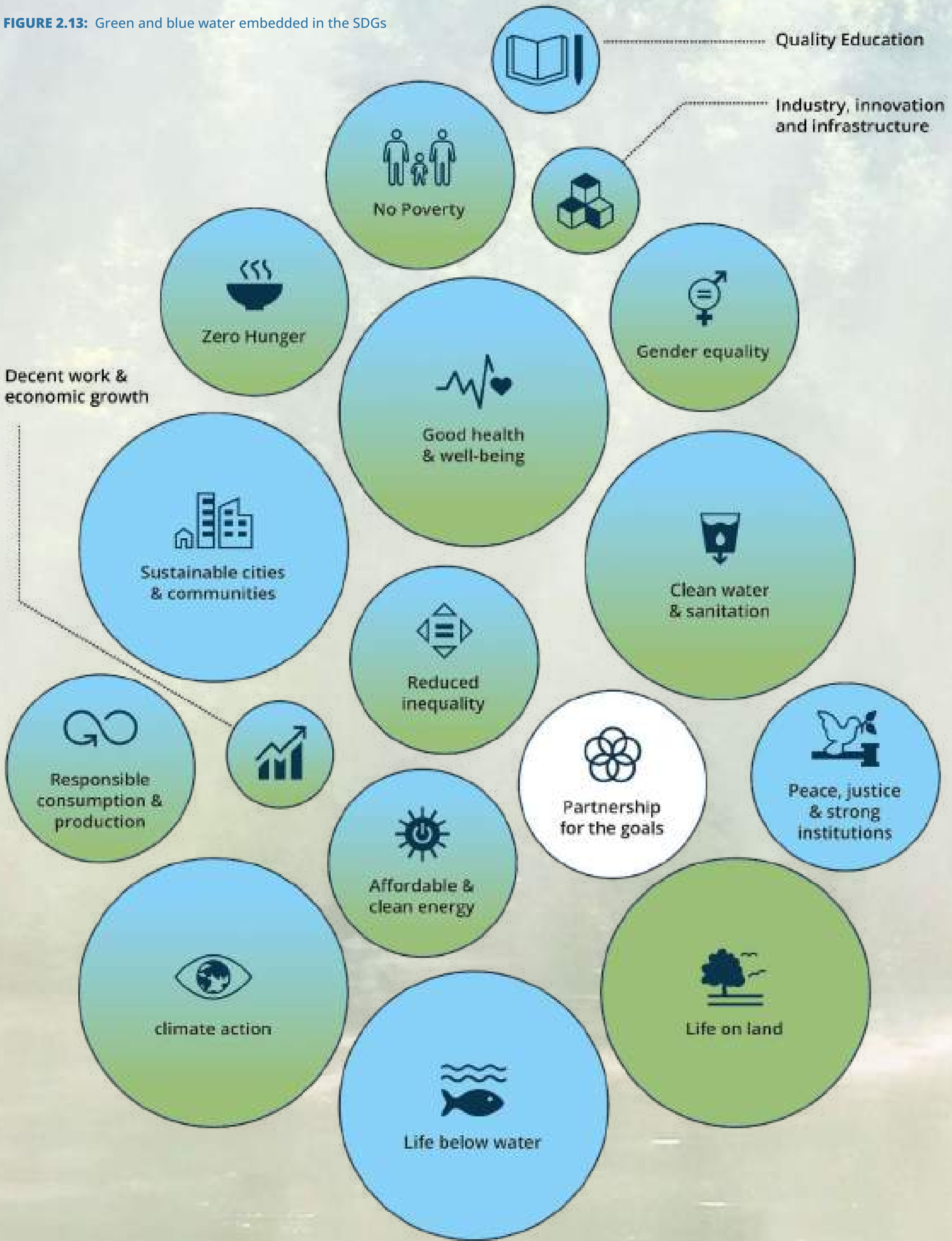
crisis. For example, when green water is lost through deforestation and unsustainable land-use practices, carbon storage is reduced in the soil and vegetation (Nabuurs et al., 2023). Hence, there is a case that the stabilisation of the hydrological cycle should play a much more prominent role in national strategies to mitigate climate change. The Paris Agreement requests to define new Nationally Determined Contributions (NDCs) every five years, and the upcoming cycle provides an opportunity for a radical reassessment of the role of water management in ambitious and effective climate-mitigation policies.

Beyond climate, the water crisis is deeply intertwined with biodiversity loss and desertification – issues that are recognised as systemic and global (IPCC, 2019). Both droughts and floods can exacerbate soil erosion and land degradation, which can create feedback loops: ever-less fertile soil that cannot support vegetation or absorb rainfall, more green water lost, and more land cleared to grow crops. Droughts and wildfires cause massive losses of biomass, carbon storage, and biodiversity. The loss of mangroves, peatlands, and other wetlands is depleting some of the Earth's greatest carbon stores. Land tenure exacerbates justice issues, as degraded lands (with low green water levels) tend to be allocated to the poorest.

Integrated water resources management (IWRM) provides an operational framework to enable the required shift. It starts from the premise that water is a shared resource that must be managed in a participatory manner to consider the needs and perspectives of all users and balance ecological, economic and equity considerations. Mainstream integrated water resources management usually applies to only blue water, is geographically constrained (usually to a river basin), and mainly focuses on how to allocate supply to meet multiple demands. Extending integrated water resources management to address green water stocks and flows, and linking that to land use change and the underlying drivers of water demand is the next frontier that needs to be addressed.

Third, water plays a direct or indirect role in achieving all the SDGs, which are crucial for global prosperity and to end poverty and reduce inequality. While water, sanitation, and hygiene have a dedicated goal in SDG 6 – "Ensure availability and sustainable management of water and sanitation for all" – water is crucial for almost all the SDGs. Significant volumes of freshwater reside behind all ecosystem services that support human well-being and the economy (Rockström et al., 2014; Dasgupta, 2021). Water regulates the climate system, provides the pre-conditions for communities and societies to thrive, and is the ultimate factor for economic development. Figure 2.13 and Table 2.3 depict how green and blue water are embedded in economic sectors, and how those connect to the SDGs. Because water is essential to the SDGs and the entire economy, the actions and choices made in a wide range of sectors affect water resources in profound ways. Water should therefore not be considered a sector, which can be managed in a siloed way or in isolation. The global water crisis must be addressed in a cross-sectoral, economy-wide manner, across all colours and hues of water.

FIGURE 2.13: Green and blue water embedded in the SDGs



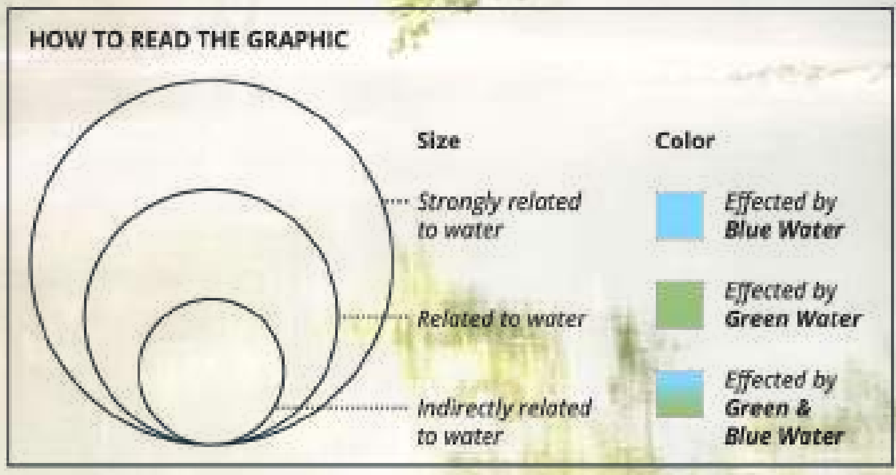


TABLE 2.3: Blue and green water relevance to each SDG

SDG		Water		How water is embedded
1	Zero poverty	Blue	Green	All (economic) activities use water. Variations in water will impact economic growth and poverty reduction.
2	Zero hunger	Blue		Irrigated (sustainable) agriculture for food security and nutrition.
		Green		Rainfed (sustainable) agriculture for food security and nutrition.
3	Good health & well-being	Blue		Access to safe WASH (domestic) is critical for disease prevention.
		Blue	Green	Basic to nutrition.
4	Quality education	Blue		WASH is basic to educational opportunites, particularly for girls.
5	Gender equality	Blue	Green	Water governance is biased against women and girls.
6	Clean water & sanitation	Blue		Safe drinking water, sanitation and hygiene. Womenget rap ed when fetching water and engaging in open defecation.
		Green		Poor sewage management affects soil and green water.
7	Affordable & clean energy	Blue	Green	Energy needs water (e.g. cooling, dams, cleaning solar panels), and water needs energy (e.g. treatment/distribution).
8	Decent work & economic growth	Blue	Green	Supporting livelihoods from farming to advanced manufacturing.
9	Industry, innovation & infrastructure	Blue	Green	Water footprint of companies and their environmental discharge into water systems (e.g. PFAS).
				(De) Centralised and infrastructure models for access, conservation.
				Natural infrastructure solutions.
10	Reduced inequalities	Blue	Green	Inequalities in water distribution exacerbates income inequality. Income in equality can encourage land- and water grabbing.
				Water pricing and access infrastructure.
11	Sustainable cities & communities	Blue		Urban sustainable water management (e.g. stormwater).
12	Responsible consumption & production	Blue	Green	High income/revenue individuals and organisations use excessive water in scope 1, scope 2, and scope 3.
				Corporate water footprint.
				Supply chain water footprint.
13	Climate action	Blue		Climate change influences water, and water influences climate change (water vapour).
		Green		Stable green water stocks essential for carbon sequestration.
14	Life below water	Blue		Aquatic ecosystem functioning.
15	Life on land	Green		Terrestrial/biosphere ecosystem functioning.
16	Peace, justice & strong institutions	Blue		Water is closely related to civil war and conflict. Strong institutions for water management can enhance human health and peace.

Managing the hydrological cycle as a global common good therefore calls for collective, systemic, and economy-wide action. Without equitably engaging more communities and countries in governing water collectively as a system, countries will fail to ensure its stability. For example, existing water governance structures have little or no influence on how land is used or how different technologies that require water evolve – much less on global markets and financial flows. The water community alone cannot solve the world's water problems at any scale. All stakeholders need to become much more aware of "how water works" and what is needed to address water challenges. There will be lessons from the climate change and biodiversity communities about how this process of socialisation of complex concepts has been carried out. All sectors, cultures, communities, and countries need to be engaged.

If governance systems can tap into the collective intelligence and resources of different actors, then countries and regions can develop more effective solutions, learning from one another and innovating together. It will not be easy: there are large disparities in wealth and political power across and within countries, as well as in the distribution of benefits and negative impacts, so the interests of stakeholders often conflict (Meta, 2003; Desai, 2003).

Agreeing to govern the hydrological cycle as a global common good has profound implications for how to do this in practice, including the remits and mandates of economic actors – from governments to business and civil society – and the design of policies, institutions, and relationships to ensure that justice is at the centre of the response. It begins by recognising that governments have an important role in proactively shaping markets for water across the economy, not just reactively fixing them.

The global water crisis, as updated here, combined with the scientific assessment of rapidly changing and increasingly unreliable freshwater resources across the entire world, calls for adjustments in the economic concepts we apply to water. First, acknowledging that blue and green water systems, though partly renewable, are finite. This implies that there are absolute limits, and thus finite budgets, to the amount of water that can be safely and sustainably consumed. For blue water, this implies that there are limits on the amount of water that can be withdrawn and limits on the concentration of pollutants. For green water, protecting the sources of supply (e.g., forests, wetlands) and integrated policies to conserve the moisture held in soils will be critical. Second, we must value water for the essential services it provides. Managing water stresses will require discouraging waste, allocating scarce water resources between sectors to obtain greater benefits, and ensuring sufficient water for ecosystems.

3. Towards a new economics of water

Key takeaways

Water provides critical environmental functions and services that support all life. The Action Plan from the United Nations Water Conference in 1977 recognised water as a human right. It is also an essential input in economic activity, with no close substitute.

New assessments indicate a concerning global trend of near-universal water stress: few people reside and few cropped acres exist in locations that have no water-resource-related stresses.

- A significant portion of the global population (about 2.9 billion people) and 55% of the world's food production are in areas experiencing drying or unstable trends in total water storage.

- Where irrigation is prevalent, its drying impact overwhelms that of climate change. In some areas, the influence of irrigation on the drying trend is more than twice as strong as the climate effect.

- Between 40% and 60% of terrestrial rainfall originates from land, with forest and natural ecosystems making significant contributions. Deforestation and other land-use changes disrupt these moisture flows, potentially exacerbating water scarcity in affected areas. These result in significant growth losses (0.5 – 0.7 percentage points) in affected areas, suggesting that the consequences of deforestation have been underestimated.

- The poorest 10% of the global population reside in locations that receive 70% of their annual precipitation from land-based sources. Consequently, they are highly vulnerable to upwind land-use changes, over which they have little or no control.

While the supply of water is becoming less stable, demand is rising exponentially with increases in living standards and demographic change. Water withdrawals have increased at twice the rate of population growth in recent decades. Constraints on the supply of water translate into slower economic activity. New modelling suggests a high human toll under a business-as-usual scenario, including:

- **GDP decline.** High-income countries are projected to experience a median 8% GDP decline, while lower-income countries could face a drop of 10-15%. These losses are larger than those projected by climate economic models that neglect the critical role of water.

- **Human capital loss.** The lack of access to safe water and sanitation exacerbates these economic impacts, disproportionately affecting poorer communities, women, and children.

- **Trade disruptions.** Virtual water exports are projected to decline, leading to a shift in export patterns. Water-stressed, lower-income countries heavily reliant on agriculture bear the brunt of these disruptions.

Agriculture consumes much of blue and green water globally, and has a disproportionate impact on the availability and sustainability of land and water resources. The magnitude of direct and indirect subsidies accruing to water users in agriculture is vast and likely exceeds

USD 630 billion per year. Empirical estimates indicate that: (1) perverse subsidies distort cropping patterns and lead to water-intensive crops being grown in arid and semi-arid regions; (2) subsidies to forest-frontier products have promoted deforestation in the tropics; (3) nitrogen fertiliser subsidies are responsible for 17-20% of nitrogen pollution from runoff; and (4) such subsidies are regressive. Findings support a growing literature that highlights the unintended consequences of policies that neglect economic incentives.

Recommendations

Four dimensions of water call for a fundamental shift in the way that freshwater stresses are assessed and managed: (1) the public-good character of freshwater functions and services; (2) the interconnectedness of global change and local freshwater supply, and the resulting uncertainties; (3) the geographic interweaving of freshwater sourcing via atmospheric moisture flows; and (4) the increasing demand for freshwater due to rising living standards and population growth.

Water is often mismanaged due to perverse incentives and inappropriate policies. Policy incentives are seldom aligned with the economic, social, and environmental values that water services provide, while subsidies often encourage water-intensive industries to locate in regions where water is already scarce. When the supply of water is increased without corresponding incentives, demand rises to meet the new level of supply, resulting in a higher level of water dependence and inefficiency.

Model results illustrate that improving resource allocation – whether tariffs or other means – renders production and consumption activities more responsive to water scarcity and opportunity costs. These effects would ripple through the economy with positive feedback to water availability and long-term sustainability. Adjusting water tariffs to reflect externalities and scarcity to address market failures and scarcity constraints is pro-poor, benefiting water-stressed lower-income countries more than higher-income countries.

Sound water stewardship can go a long way towards mitigating the adverse effects of shifts in water availability in the face of climate change. Aligning economic incentives to reflect the value generated by green and blue water could yield a triple dividend:

- **Economic efficiency and resilience.** Water-related impacts of climate change can be largely neutralised, improving climate resilience.
- **Equity.** Economic benefits accrue mainly to the poor.
- **Environmental sustainability.** Resource depletion is mitigated, safeguarding the environment.

As global populations rise and water supplies are disrupted by land-use change, the challenges will worsen, calling for urgent and bold reforms, and new policies that can address pressures of such scale and magnitude. Three overarching policy principles can lead the world to greater water security through efficiency, equity, and environmental sustainability.

Principle 1: Value water for the essential services it provides. Managing water stresses will require discouraging waste and allocating scarce water resources between sectors to obtain greater benefits. This could be achieved through infrastructure and regulation, or through better incentives such as pricing and trade. Any policy regime would need to include safeguards to assure access for poor households and environmentally sustainable and prudent uses.

Principle 2: Establish absolute limits to ensure sustainability. Acknowledging that the economy is embedded in the biosphere, and that blue and green water systems are generally renewable but also finite, implies that there are absolute limits to the amount of water that can be safely and sustainably consumed. For blue water, this implies limits on the amount of water that can be withdrawn and on the concentration of pollutants in freshwater. For green water, this will mean protecting the sources of supply (forests and wetlands) with incentives and policies to conserve the moisture held in soils.

Principle 3: Develop policy packages to promote synergy. No single policy can achieve the multiple goals of efficiency, equity, and environmental sustainability. Policy packages will need to address the trade-offs that emerge. Complementary policies are needed to address distortions in related sectors that can stymie reform. For instance, subsidies to water-intensive industries would undermine the effectiveness of water prices in regulating demand. While these policy reforms will be demanding, the consequences of inaction will be far higher.

Why is managing water to promote well-being difficult? Water is a distinct natural resource that delivers multiple functions and services at multiple geographic scales. Being essential for survival, it was proposed as a human right by the Action Plan from the United Nations Water Conference in 1977. At its source, in rivers, forests, wetlands, and soils, it provides ecosystem services and functions that are public goods. These include ecological functions such as pollination, biomass growth, soil productivity, and maintaining the energy balance on Earth through the different states of water (liquid, ice, vapour). It is also an indispensable input to all economic activity, with no close substitute.

Given the wide range of functions and services provided by water, its management requires balancing the often-competing goals of economic efficiency, equity, and environmental sustainability while navigating difficult trade-offs.

With the rapid changes and imbalances occurring in Earth systems, economies must consider a new dimension of freshwater's impacts on economic development: namely, changes in precipitation as the ultimate origin of all freshwater, be it blue water in rivers, lakes and groundwater, or green water in soils and as evapotranspiration through plants. Global environmental change, particularly land-use and climate change, are altering the hydrological cycle at all scales, from local to global, increasing uncertainty in the year-to-year supply of stable precipitation. This affects all regions of the world, from temperate-cold to arid-hot hydroclimates, and impacts all economic sectors. In addition, as pointed out in Chapter 2, 40-60% of precipitation on land originates from Land-to-Land supply, not from Ocean-to-Land supply, which means the performance of neighbouring, upwind economies is a core factor in managing green-water-supplying ecosystems as sources for atmospheric moisture flows and precipitation downwind. Adding to these challenges, while the supply of water is becoming less stable, demand for it is rising exponentially with increases in living standards and demographic change. Water withdrawals have increased at twice the rate of population growth in recent decades (Dinar, 2024).

Together, these four dimensions – (1) the public-good nature of freshwater functions and services at all scales, (2) the interconnectedness of global change and local freshwater supply, and the resulting uncertainties, (3) the geographic interweaving of freshwater sourcing via atmospheric moisture flows, and (4) the increasing demand for freshwater – call for a fundamental shift in the way freshwater stresses are assessed and managed.

Current water policies are not designed to address pressures of such scale and magnitude, and often inadvertently exacerbate the degradation of water resources. Policies seldom allocate water in ways that reflect the types of value it creates, while subsidies often encourage water-intensive industries to locate in regions where water is already scarce. Nor have costly investments in water storage and infrastructure provided lasting relief. When the supply of water is increased without corresponding incentives, demand rises to meet the new level of supply, resulting in a higher level of water dependence and inefficiency. Powerful economic forces have transformed well-intentioned policies, into documented failures.

Adjusting to the new realities will call for significant reforms built on three overarching principles: the need to (1) value water for the critical economic, environmental, and social services it provides; (2) establish absolute limits to the amount of water that can be used safely and sustainably; and (3) implement policy packages to address trade-offs and achieve the triple goals of economic efficiency, equity, and environmental sustainability.

Translating these principles into effective policies will be challenging. It will be necessary to first identify where water-related risks and hotspots are most severe, then to understand what drives these changes – natural forces such as temperature and rainfall, or profligate management practices – and finally to assess the costs of inaction to determine whether reforms and changes that entail trade-offs are warranted. This chapter provides information to help answer these questions.

The first part of the chapter explores the effects of blue and green water on well-being, providing new estimates of the incidence and magnitude of impacts. It focuses on the economic significance of atmospheric moisture flows, since their contribution is not known despite accounting for 40-60% of rainfall. The second part of the chapter deals with blue water management and outlines the broad contours of a policy approach to achieve greater efficiency, equity, and environmental sustainability.

Drivers, impacts, and risks of changing water endowments

Drawing upon the analysis in Chapter 2, which identified prominent markers of water stress – declining total water storage (TWS), aridity and groundwater depletion – this section explores the intersection between water-related stresses and socioeconomic factors and vulnerabilities.

The socioeconomic impacts of water scarcity are likely to be more severe in places where high demand and vulnerable populations converge. Demand for water is typically higher in densely populated regions and those where agriculture is the primary economic activity. Vulnerable populations, identified using the Human Development Index (HDI) as a proxy, have low income and limited human capital, and are known to be more vulnerable to exogenous shocks and stresses. While rigorous research on the socioeconomic impacts of growing water scarcity is limited, evidence suggests that vulnerable populations struggle to adapt to growing water scarcity and often abandon farming or migrate (Fishman et al., 2024; Zaveri et al., 2021).

A region is more likely to endure some level of water risk if it is exposed to at least one supply-side stress factor (such as aridity, or declining total water storage or groundwater scarcity) or one demand-side stress factor (such as high population or cropped area, or a low HDI score). Figure 3.1 shows that relatively few people live and little cropland is cultivated or irrigated where there are no water related stresses. It reveals:

- **Combined supply and demand challenges.** There are severe water challenges in northwestern India and parts

- of northeastern China, where water stress, demand, and socioeconomic vulnerability are all high.

- **Areas of water stress, but low vulnerability.** Large regions of the United States, Middle East, and Australia face water stress, but relatively low socioeconomic vulnerability. Nevertheless, if food supplies are adversely impacted, resulting in higher prices, there could be spillover effects to other, more-vulnerable regions.

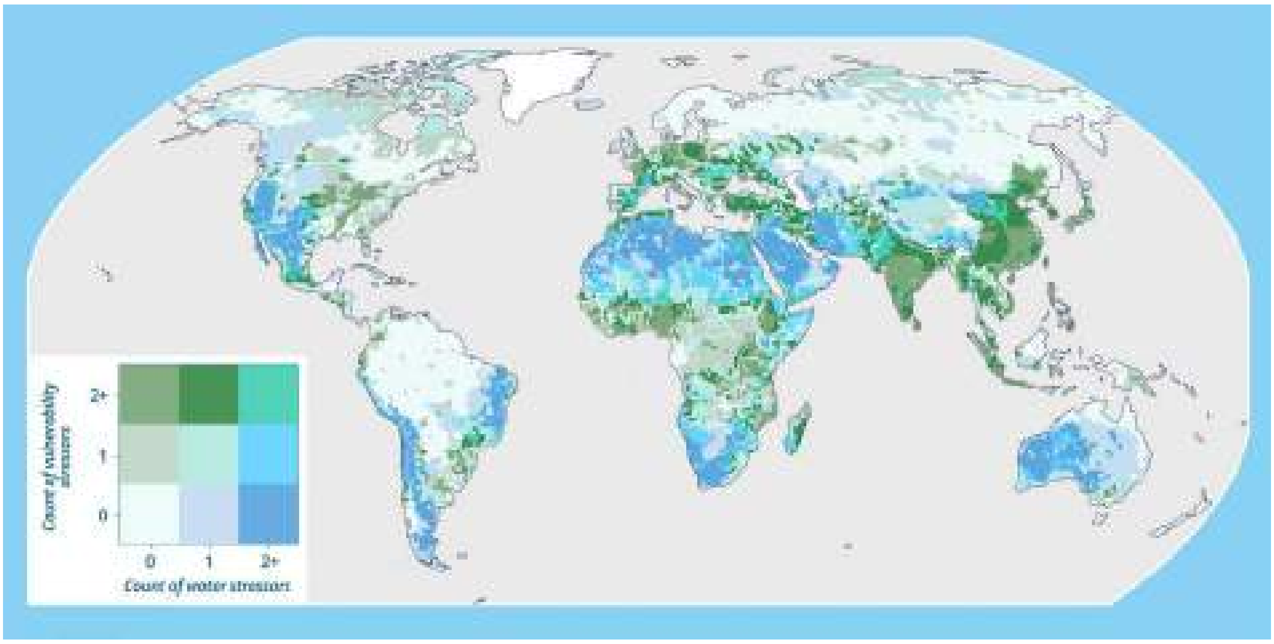
- **Relatively low-population densities and low cropped areas.** Regions where water stress is low, tend to have comparatively lower population densities and lower levels of crop cultivation, reflecting limited demand for water.

- **Opportunities.** A notable exception emerges in some areas of central Africa, where poverty is high and the HDI is low, but total water storage is increasing over time. These present an opportunity for sustainable agricultural expansion (see Box 3.1) for some of the most disadvantaged populations.

These findings point toward a future of potential water risks, most often in the regions where people and economies have the greatest need. A large portion (55%) of the world's food is cultivated in areas with declining total water storage, which implies fewer water resources available underground, in the soil, and in surface water reserves for use in both rainfed and irrigated agricultural systems. Specific concerns arise in irrigated areas, responsible for roughly 40% of global agricultural value, making these critical to food security (Mehta et al., 2024). An estimated 23% of global cereal production could be lost if irrigation becomes unfeasible where total water storage declines are extreme,[1] with significant ramifications for food prices and food security (Appendix 3.2). Some of the most productive and important agricultural lands are at high risk of crop losses if irrigation cannot be sustained, such as northern India, northeastern China, and around the Mediterranean (Figure 3.2).

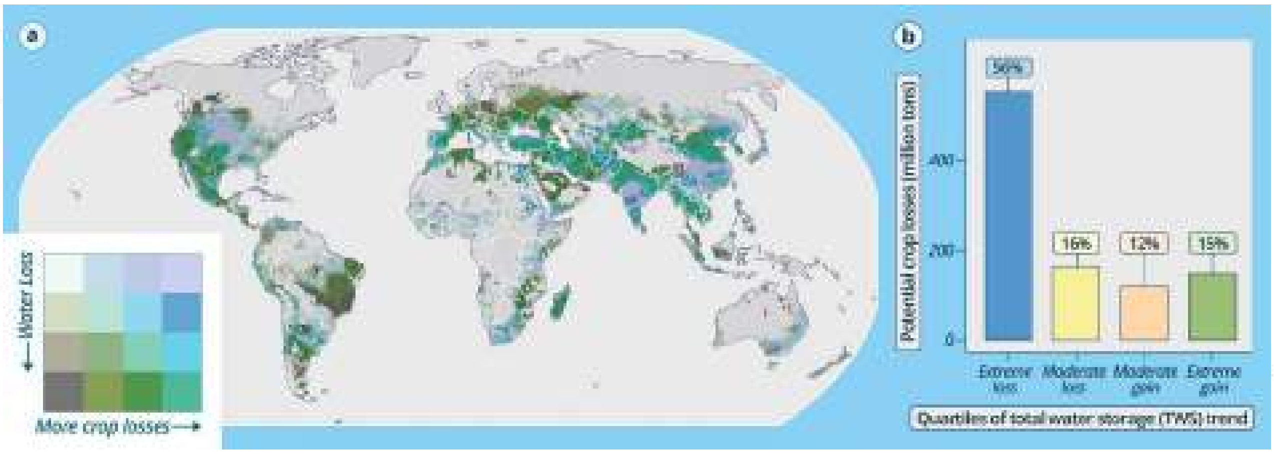
1 'Greatest' or 'extreme' loss is defined as the lowest quartile of the distribution, with total water storage trends below -0.40 cm per year.

FIGURE 3.1: Aggregate social and economic vulnerability to water stress



Note: The map shows the combined vulnerability and water stressors in each region. Vulnerability stressors include: (1) being in the highest quartile of the global population distribution; (2) being in the lowest quartile of the global HDI distribution; (3) being in the highest quartile of the global cropped area distribution; and (4) being in the highest quartile of the global irrigated cereal production distribution. Water stressors include (1) being in the lowest (fastest-depleting) quartile of total water storage; (2) being in the lowest quartile of groundwater depth; and (3) being in the lowest quartile of global aridity distribution.

FIGURE 3.2: Potential output losses if irrigation is not feasible



Notes: (a) The map shows trends in total water storage (TWS) against potential cereal production losses if the land would no longer be irrigated. Potential cereal production losses are estimated from FAO-GAEZ data by calculating the difference between irrigated potential production and rainfed potential production in currently irrigated areas for wheat, rice, sorghum, millet, maize, and barley. Regions in white are those in which irrigation is currently absent. (b) The bar plot shows the distribution of all current cereal production gains derived from irrigation across the quartiles of the global TWS trend distribution. Quartile 1 (extreme loss) contains TWS trends below -0.40 cm per year, Quartile 2 (moderate loss) between -0.4 to -0.04 cm per year, Quartile 3 (moderate gain) between -0.04 and +0.30 cm per year and Quartile 4 (greatest extreme gain) above 0.30 cm per year. Greatest or extreme loss is defined as the lowest quartile of the distribution, with TWS trends below -0.40 cm per year. Trends in TWS are recovered from GRACE and reported in prior work. These show that annual changes can be small compared to average precipitation. The Appendix shows that these effects become more severe with climate change and that year-on-year impacts compound over time. It is shown that 38% of the population lives in the 25% of cells losing water fastest. If these losses persist, the compound impacts would be a concern. Together, these results show that just 31% of the population are in regions where water resources are stable.

Box 3.1. Groundwater for the future of Africa's agriculture

Agricultural productivity in sub-Saharan Africa is critical to addressing poverty and providing food security. The gap between potential and actual crop yield is notably wide in Africa largely driven by low land and labour productivity. Much of the output increase achieved in recent years has come about through extensification, or the expansion of agricultural land into marginal lands and bringing forest areas under cultivation. This approach is not sustainable with growing populations and degrading soils.

Irrigation levels in Africa are low and below their sustainable potential (Rosa et al., 2020). Most policymakers and much of the literature reflexively assume that increases in irrigation will entail increasing surface water storage in large lakes or dams, such as Lake Nasser and the Grand Ethiopian Renaissance Dam. These call for significant investments that are difficult to finance in low-income countries, and that have adverse environmental consequences and debilitating social impacts from the submergence of productive land, displacement of vulnerable populations, loss of biodiversity and release of methane emissions from rotting reservoir vegetation.

However, recent satellite data shows a more benign and cost-effective alternative is available. Groundwater in some parts of Africa is a vast, untapped resource. The annual groundwater recharge (1,500 km^3) is estimated by Scanlon et al. (2022) as equivalent to the combined annual flow of all the major rivers of Africa: the Congo, Nile, Niger, and Zambezi. Another positive feature of Africa's aquifers is that recharge rates correlate inversely to storage capacity (McDonald et al., 2021). Hence, rapid recharge of shallow aquifers provides an opportunity for higher sustainable abstraction rates, while large storage capacity in deep aquifers can provide a buffer for times of stress.

Groundwater can therefore be a cost-effective and environmentally attractive way to manage water scarcity and rainfall variability, and boost productivity if it is managed for efficiency and sustainability and considers the needs of groundwater dependent ecosystems and the services they provide. With the increasing availability of cheap, solar-powered pumps, there is an opportunity to invest in systems that tap into Africa's groundwater resource to buffer against rainfall variability and increase yields.

There is an important caveat. Africa can learn and improve upon experiences elsewhere, and utilise new monitoring technologies and information to ramp up production without depleting and polluting its aquifers or degrading its groundwater-dependent ecosystems. But this will require different natural resource management systems. Despite rapid urbanisation, rural agricultural water demands will rise further, highlighting the need for systemic reforms.

Drivers of change in total water storage

Understanding what drives changes in total water storage is essential to addressing the risks of hydrological imbalances. If climate change is the main culprit, it would call for a focus on climate adaptation strategies. Conversely, if drying trends are a consequence of irrigated agriculture, this underscores the need for improved water resource management in agriculture. Identifying the role of agriculture is important as it accounts for 80-90% of blue water consumption (Hoekstra & Mekonnen, 2012; D'Odorico et al., 2019) and is a major contributor to ecosystem degradation and tropical deforestation.[2] This subsection provides initial insights into the drivers of total water storage changes, acknowledging the limitations of the data and climate uncertainty. Methodological details are provided in Appendix 3.2.[3]

Figure 3.3 shows the combined effects of temperature and precipitation trends over 2003-22. Observed warming trends have significantly accelerated water loss in most regions.

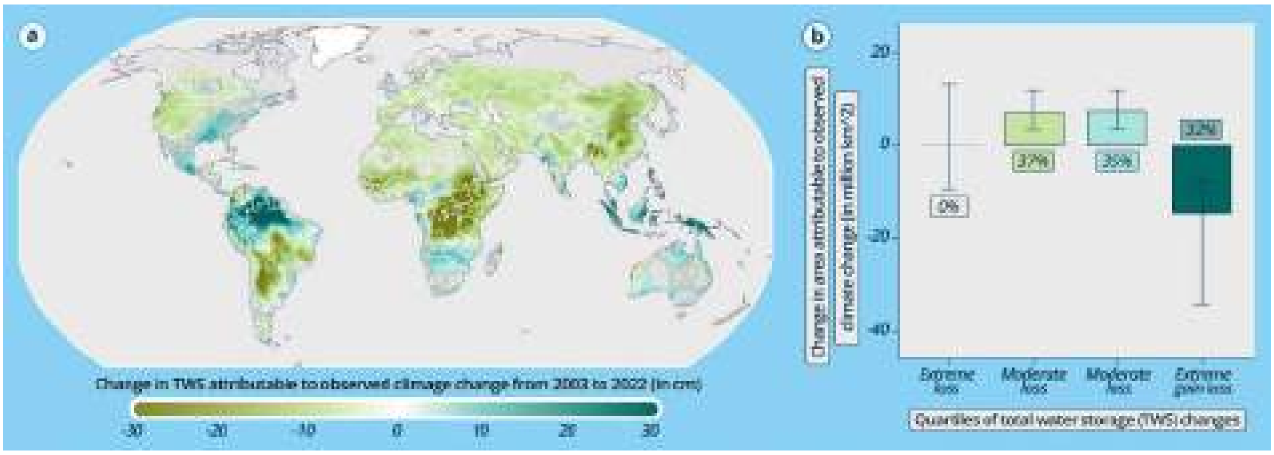
2 Note that while other human activities such as energy cooling systems and mining withdraw substantial amounts of water, these generally return water directly to the local environment. In contrast, crops evapotranspire withdrawn water, generating true local losses in water storage.

3 Overall, this assessment indicates that recently observed trends in temperature and precipitation have had spatially variable impacts on total water storage. Observed warming trends have significantly accelerated water loss in almost all regions of the world, with few exceptions. On average, every 1°C of additional warming is estimated to accelerate rates of water loss by -0.3 cm per year (95% CI: 0.14-0.62 cm per year). As a result, observed warming over 2003-22 is estimated to have increased the share of arable land experiencing net total water storage loss by 53% (95% CI: 21-136%). In some locations, heterogenous variations in rainfall have ameliorated these drying trends. On average, a decline of 1 cm in annual precipitation is estimated to accelerate water loss by around 0.04 cm per year (95% CI: 0.02-0.05 cm per year).

However, increased precipitation in some locations has mitigated this. On average, a decline of 1 cm in annual precipitation is estimated to accelerate water loss by around 0.04 cm per year (95% CI: 0.02-0.05 cm per year).[4] This finding is based on regression analysis and is consistent with previous estimates showing that changes in total water storage are smaller than fluctuations in precipitation. Appendix 3.3 Figure A2 provides a global decomposition of these effects into those driven by temperature versus precipitation.

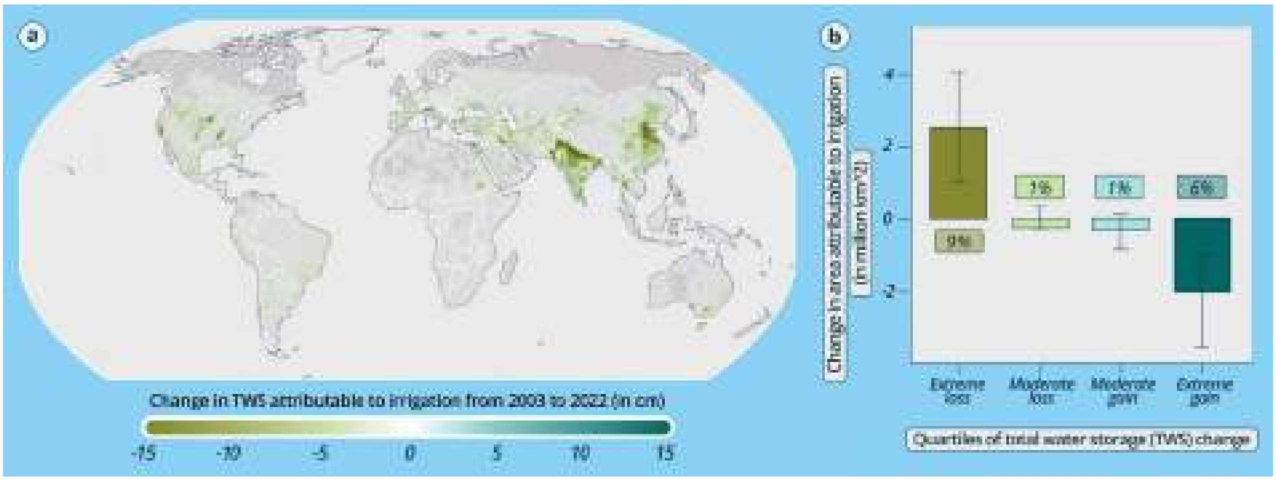
Where irrigation is prevalent, it dominates the effects of temperature and precipitation. On

Figure 3.3: Trends in total water storage due to historical shifts in temperature and precipitation



Notes: (a) Changes in total water storage (TWS) attributable to climatic change are derived by combining observed changes in the climate obtained from the ERA5 reanalysis dataset with statistical estimates of the TWS-temperature and TWS-precipitation associations (Appendix 3.2). Regions in grey have no arable land. Stippling indicates where impacts of observed climate change are not statistically distinguishable from zero, using a 95% confidence interval derived from block bootstrapping. (b) The bar plot shows changes in the arable land exposed to each quartile of the observed TWS change distribution that have occurred because of observed temperature and precipitation trends, relative to a counterfactual scenario with the 1951-70 climate. Quartile 1 (extreme loss) contains TWS trends below -0.40 cm per year, Quartile 2 (moderate loss) between -0.4 to -0.04 cm per year, Quartile 3 (moderate gain) between -0.04 and +0.30 cm per year, and Quartile 4 (extreme gain) above 0.30 cm per year. Whiskers indicate 95% confidence intervals obtained through bootstrapping.

Figure 3.4: Trends in total water storage due to irrigation



Notes: (a) Changes in total water storage (TWS) attributable to irrigation are derived by combining data on the average area equipped for irrigation in 2000-15 with an estimate of the TWS-irrigation association (see Appendix 3.2 for details). Regions in grey have no arable land. Stippling indicates where impacts of observed irrigation are not statistically distinguishable from zero, using a 95% confidence interval derived from block bootstrapping. (b) The bar plot shows changes in the arable land exposed to each quartile of the observed TWS change distribution that have occurred because of irrigation, relative to a counterfactual scenario without irrigation. Quartile 1 (extreme loss) contains TWS trends below -0.40 cm per year, Quartile 2 (moderate loss) between -0.4 to -0.04 cm per year, Quartile 3 (moderate gain) between -0.04 and +0.30 cm per year, and Quartile 4 (extreme gain) above 0.30 cm per year. Whiskers indicate 95% confidence intervals obtained through bootstrapping.

4 The estimated effect represents the average treatment effect of precipitation on total water storage for the globe.

average, fully irrigated locations lose around 1.6 cm (95% CI: 0.72-2.87 cm) more water storage per year than unirrigated regions.[5] This is about 58% greater than the loss in locations with the most rapid (lowest quartile) total water storage depletion due to climate change. The effect is similar in magnitude to that of 5 degrees warming. Figure 3.4 displays changes in total water storage attributable to irrigation. In northwest India and northeast China, the historical effect of irrigation on water storage was on average twice that of the estimated effect of climate change. Overall, irrigation has increased the global share of arable land experiencing extreme water loss by 9% (95% CI: 4-16%).

Since the analysis is based on Gravity Recovery and Climate Experiment (GRACE) grid cells that are large (around 110 km per side), it is not possible to assess whether drying in one location has impacts upon the wider landscape. Nevertheless, the results are consistent, with irrigation outflows exceeding inflows to the system. In policy terms, this suggests the need to improve efficiency and relocate production, especially where climate change is likely to increase rates of water loss.

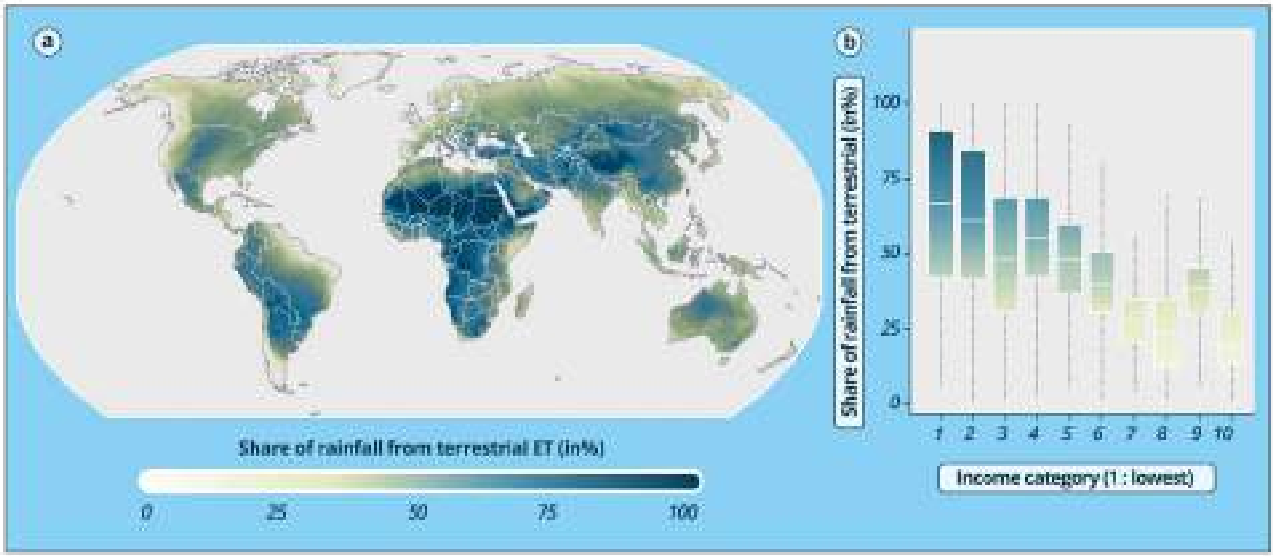
These findings support a growing literature that highlights the unintended consequences of policies that neglect economic incentives. When irrigation water is supplied for free or at a subsidised price, it signals that water is abundant and farmers respond by irrigating beyond sustainable limits.

The economic impacts of terrestrial moisture recycling

Land-use change significantly influences precipitation patterns across regions (Keys et al., 2019). About 40-60% of rainfall over land originates from land-based evapotranspiration – known as terrestrial moisture recycling (TMR) – much of which comes from forests, cropland, and large water bodies (De Petrillo et al., 2024). This creates a complex, global web of influence between land use and rainfall. However, little is known about the economic significance of these links. This section provides an initial assessment of the economic contribution of terrestrial moisture recycling.

The assessment suggests that large shares of the global poor and of rainfed agricultural lands are reliant on precipitation originating from terrestrial moisture recycling (Figure 3.5). A striking finding is that the poorest decile of the global population receives nearly 70% of its annual precipitation from terrestrial moisture recycling. In contrast the richest

Figure 3.5: Share of total precipitation from terrestrial sources



Notes: (a) The map shows the share of total rainfall in each region that originates from terrestrial evapotranspiration (ET), as derived from the Utrack model (Tuinenburg & Staal, 2020) in combination with ERA5 precipitation data (Appendix 3.1). Darker blue indicates that more rainfall originates from land-based moisture flows (i.e., greater dependence on terrestrial moisture recycling). (b) The plot shows the average share of total rainfall sourced from terrestrial evapotranspiration for regions in each decile of the global income distribution. Regions are divided into income categories using GDP data from Kummu et al. (2018).

5 The estimated effect represents the average treatment effect of irrigation on total water storage for the globe.

decile obtain only around 20% of rainfall from terrestrial sources. Further, regions that generate a substantial amount of terrestrial-moisture-recycling-driven rainfall in poorer areas coincide with deforestation hotspots, placing them at greater risk of precipitation declines as described in appendix (Harris et al., 2017).

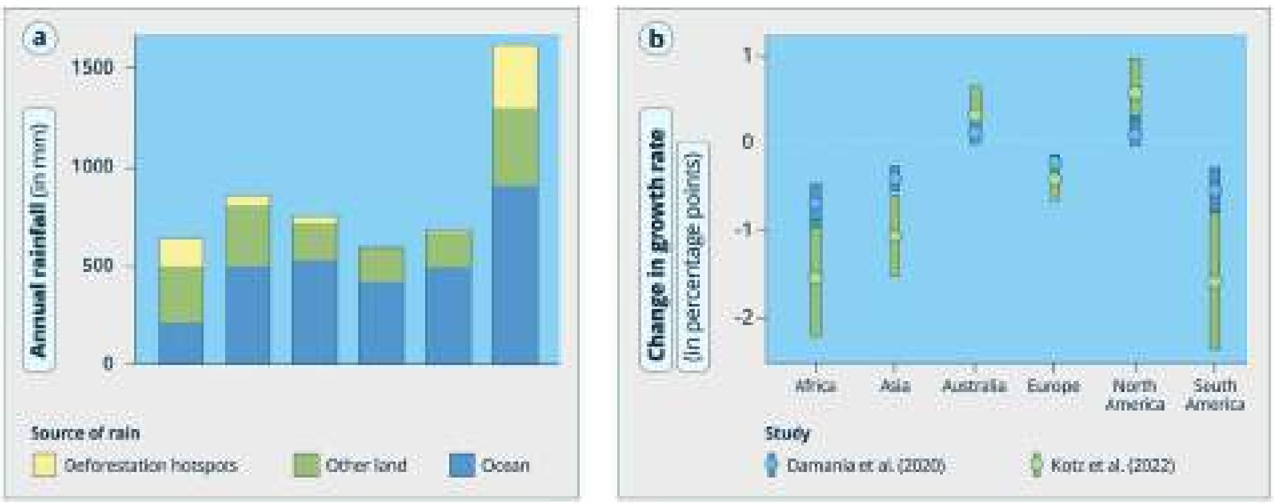
Figure 3.6 illustrates that the elimination of all TMR flows in Africa and South America would result in a fall in gross domestic product (GDP) growth of 0.5 (95% CI: -0.28, -0.69) and 0.7 (95% CI: -0.38, -1.04) percentage points per year, respectively (Appendix 3.3). Agricultural output would be similarly impacted, with declines in growth in these regions estimated at 0.7 (95% CI: -4.65, 0) and 0.6 (95% CI: 2.58,0.28), respectively. Given that long-term global economic growth averages around 3.8% a year in Africa and 1.9% in South America, these declines represent a significant impediment to progress. The estimates suggest that the marginal losses from TMR-related rainfall reductions are nonlinear and generally more pronounced where rainfall is low and economic activity depends heavily on precipitation.

A caveat should be noted: the empirical estimates used to derive these projections are statistically determined short-term responses in GDP and agricultural output growth to rainfall variations. The longer-term effect of a permanent reduction in terrestrial moisture recycling could be weakened or enhanced through economic adjustments. Nevertheless, the findings imply that terrestrial moisture recycling is a materially important input to the economy. Estimates of the economic contribution of forests have neglected this important ecosystem service and thus severely underestimate the economic value of forests.

Estimating the costs of inaction

The economy is a thirsty system, and water is a critical factor of production. As a result, diminishing water supplies translate into slower growth. This is particularly true in countries that are water dependent and where water scarcity is a pressing issue. The economic modelling in this section assesses the consequences of inaction in the face of diminishing water supplies to 2050. It shows that bad water-management policies exacerbate the adverse impacts of water stresses, while good policies can neutralise adverse effects and generate positive impacts. The costs of inaction are explored in a workhorse computable general equilibrium model (Box 3.3) using the standard Global Trade Analysis Project (GTAP) suite of economic data, combined with soft-links to data from GRACE estimates on total water storage, and Lund-Potsdam-Jena managed Land (LPJ-mL) model information on temperature, rainfall and green water (Chapter 2). As with all simulations, the results should be interpreted as model projections and not future forecasts.

Figure 3.6: Estimated growth effects of removing terrestrial moisture recycling



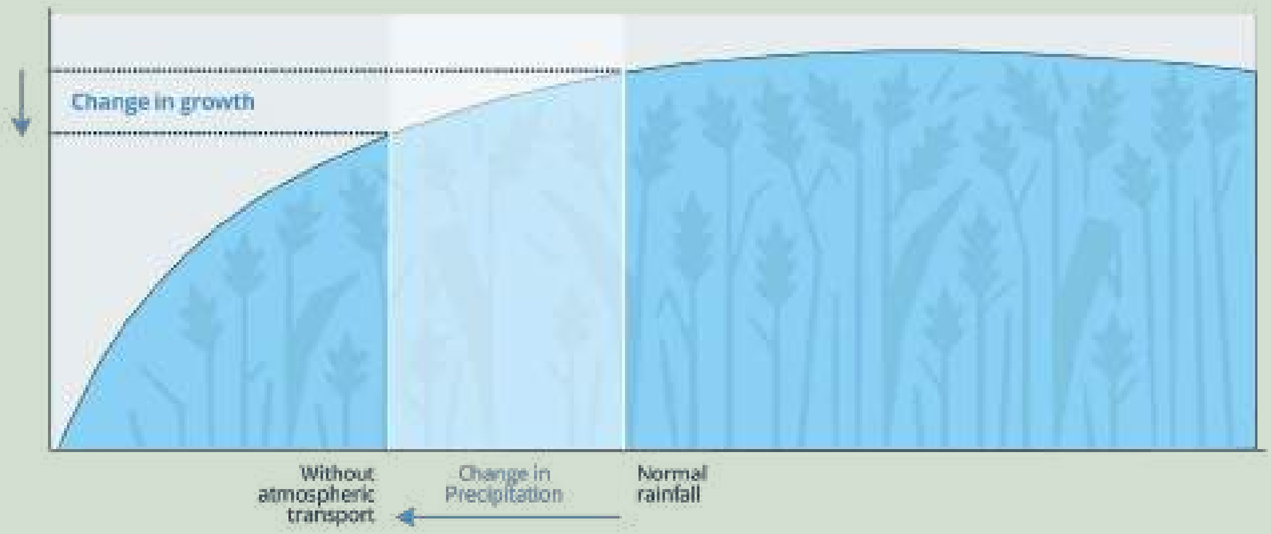
Notes: (a) The bar chart shows the breakdown of precipitation by source-type aggregated by continent. Deforestation hotspots are as identified by Harris et al. (2017), aggregated by continent. **(b)** The plot shows the estimated average change in GDP growth rates from removing all terrestrial precipitation (green and brown segments of bars). (Appendix figure A6 shows the analogous estimates from removing terrestrial precipitation only from deforestation hotspots). Changes are calculated using estimates of the impact of precipitation shocks on economic growth from Kotz et al. (2022) in gold and Damania et al. (2020) in grey. Dots indicate the point estimates, while error bars indicate statistical uncertainty in the GDP growth rate change estimates using 95% confidence intervals obtained through block bootstrapping (Appendix 3.2).

Box 3.2. Calculating the socioeconomic effects of terrestrial moisture recycling flows

The growth impacts in Figure 3.6 are based on new econometric estimates linking aggregate economic and agricultural (crop and livestock commodities) output to changes in precipitation. These are used to conduct simulation exercises evaluating the impacts that various future land-use scenarios might have on terrestrial moisture recycling. This is a partial-equilibrium calculation best interpreted as a short-term effect that will induce further economic adjustments. It provides the first global estimate of the magnitude of economic benefits generated by terrestrial moisture recycling. In a second step, these results can be assessed in a computable general equilibrium model that would allow for economic adjustments to changing conditions.

Existing literature provides causal empirical estimates of the effect of precipitation on growth rates of GDP (Kotz et al., 2022; Damania et al., 2020) and agricultural productivity (Ortiz-Bobea et al, 2021). These estimates are used to quantify the effect of removing precipitation derived from terrestrial moisture recycling in a location. Figure B3.2.1 illustrates the method used to conduct this calculation in a stylised illustration of the effects of rainfall on economic/agricultural output growth.

Figure B3.2.1: Changes in GDP or agricultural output growth rates due to terrestrial moisture recycling, using established precipitation-growth response functions



Since water is a ubiquitous input, used explicitly or implicitly in all economic activity, there is uncertainty about the channels of impacts on the economy and how these interact to offset or magnify economic outcomes. To account for this uncertainty, projections are usually based on a range of parameters. This section accounts for parameter and outcome uncertainty to identify outcomes that are robust across a range of circumstances.

Temperature and precipitation changes

A novel feature of the model is its focus on how rainfall and water storage impact the economy. The results are based upon the "moderate climate change scenario", or the Intergovernmental Panel on Climate Change (IPCC) Representative Concentration Pathway (RCP) 4.5. Should water-related impacts be troublesome in this scenario, the predicament would be far grimmer in less optimistic futures.

Many impacts of climate change would be mediated through shifts in the hydrological cycle. Yet climate-econometric models struggle to identify and estimate the effects of changing hydrological patterns. These usually find that temperature has a large impact on economic outcomes, but that precipitation has a smaller, second-order or even a null impact. This result is not credible, and recent empirical work explores the reasons for these estimates (Appendix 3.4).

Box 3.3. Modelling the economic effects of climate change

Computable general equilibrium models are a standard tool, widely used in economics to inform important policy decisions on issues ranging from trade agreements and impacts of infrastructure or industrial policy, to climate change, conservation strategies, and water resource management issues that could have long term consequences. Appendix 3.5 provides further details on methods and data sources.

As any modelling exercise, this approach has caveats and limitations. The results of any simulation exercise reflect the assumed structure of the model, and its calibration and parameterisation. A further complication is that models must grapple with uncertainty from myriad unknowable factors, such as future policies, growth rates, and the state of the environment. The outcome of a modelling exercise should thus not be viewed as a forecast of what will occur, but a projection that reflects the structure of the model and the scenario considered. Notwithstanding, models are useful to understand if current water imbalances will have significant economic impacts.

The computable general equilibrium model used for this exercise contains a representation of the world economy for 165 countries, and 14 production sectors and corresponding commodities. It uses data from several international statistical sources (e.g., GTAP 11, FAO, Water Footprint Network), and inputs from biophysical models, economic databases, econometric estimates and climate change projections. The model mimics a global system of economic agents (consumers, producers, governments) in interconnected markets where the endogenous variables (prices and quantities) are jointly determined. Parameters encompass production and utility functions, and include input-output coefficients; income shares of consumption for different commodities; and shares and elasticities of substitution for land, labour, capital, and water for different sectors and locations.

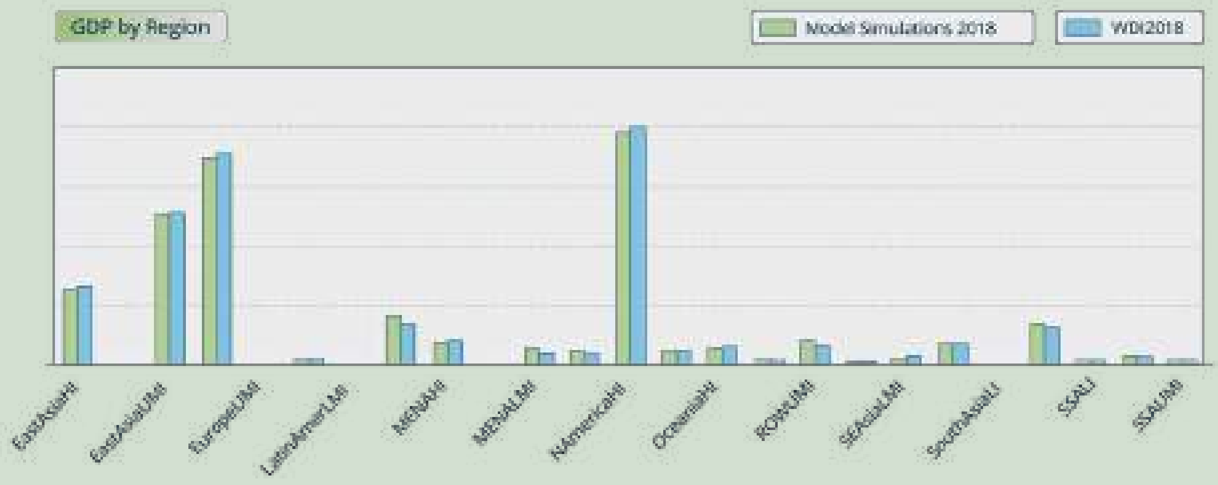
Green water influences total factor productivity in agriculture. Blue water is modelled as a primary resource and input in all economic activity. The model allows for unemployment and can distinguish high- and low-income and skill categories. The model's solutions provide a framework to investigate how markets adjust to exogenous shocks. Although caution is required due to differing underlying assumptions, these results align with the Balanced Growth Equivalents (BGEs) from the Stern review (2006) of the economics of climate change.[6] To have a more concrete reference for the scale and timing of changes, these "snapshots" are projected over a 30-year timeline using OECD forecasts and data.

Figure B3.3.1 shows that the model projects the current situation with accuracy, capturing variations in factor incomes and overall economic activity. It can therefore provide a reasonable foundation upon which to investigate water imbalances in the short to medium term. The model operates in a stochastic framework due to significant uncertainties in climate change's predictions, using Monte Carlo simulations to explore a range of potential outcomes. Its point estimates are on the high side because these are projections (not forecasts) that integrate potential impacts on both economic levels and long-term growth.

Furthermore, unlike climate-change studies that focus on temperature, this model also allows for costs due to changes in precipitation patterns and water availability for production, consumption, sanitation, and health. The interval estimates align with results from the literature and from sources like the IPCC that emphasise the risks of delaying mitigation efforts.

6 For a detailed discussion of the assumptions and issues underlying the BGEs, see: Mirrlees, J.A. and Stern, N.H. (1972), "Fairly good plans", *Journal of Economic Theory*, *4*(2), pp.268-288; and Anthoff, D. and Tol, R.S. (2009), "The Impact of Climate Change on the Balanced Growth Equivalent: An Application of FUND" in *Environmental and Resource Economics*, 43, pp. 351-367.

Figure B3.3.1: Model simulations for GDP by region



Addressing uncertainty and aggregation effects

Models of economic impacts of climate change face uncertainties in parameters and variables. These include double-counting effects of temperature, precipitation, and related impacts across multiple sectors. They also include the potential for overlooking critical issues like aquifer depletion and climate-ecosystem feedback loops: model inputs might include the impact of increased temperature on agricultural productivity and water resources independently without accounting for the fact that changes in one can directly affect the other.

In addition to a careful model design to balance these risks, a two-fold strategy has been adopted to treat uncertainty in modelling the cost of inaction. This strategy accounts for the complexity of the computable general equilibrium database and the economic interactions it simulates. It has two main components: (1) scenario analysis, simulating temperature, precipitation, and total water storage changes separately and jointly to provide a spectrum of results under different economic and environmental conditions; and (2) stochastic modelling (Monte Carlo simulations), treating key inputs as random variables with specific probability distributions rather than fixed values, allowing for a range of outcomes to be explored.

The cumulative impact of changes in temperature and precipitation, along with variations in total water storage should be considered with caution, since total water storage might also be affected by changes in temperature and precipitation. To address this problem, bootstrap regression analyses on model outputs were undertaken and indicate that 20–28% of total water storage impact could be attributable to climate change. Consequently, the estimated impact was adjusted downward.

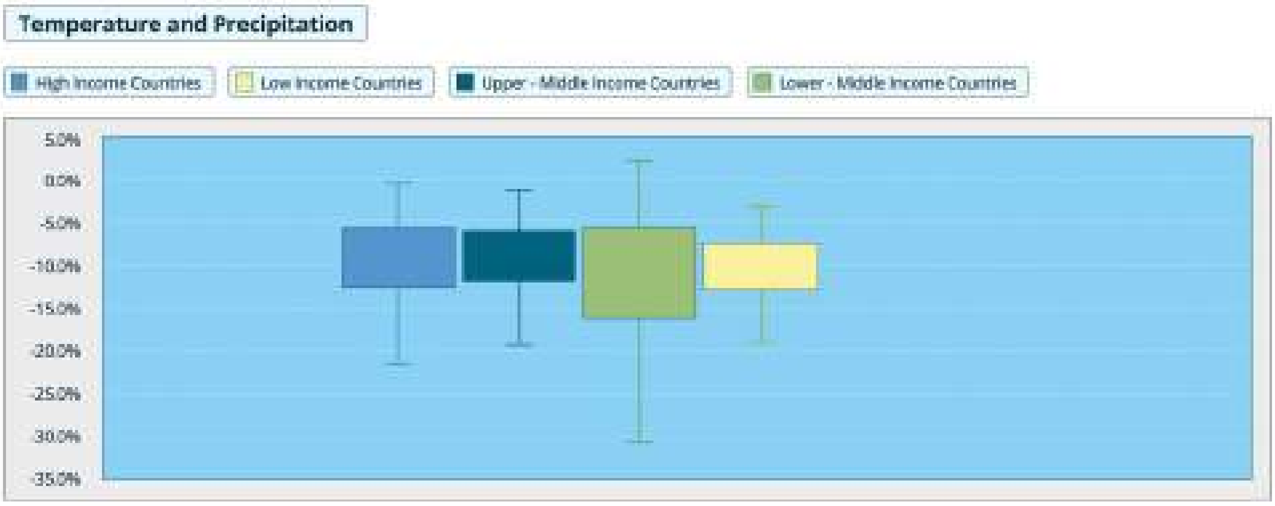
Considering rainfall and temperature effects, the economic impacts would be substantial (Figure 3.7). Simulations indicate a median GDP decline of approximately 8% from the business-as-usual scenario (with significant variation due to uncertainty) and marked disparities across regions and income groups. Food production (Appendix 3.4) would be affected severely, with more pronounced declines in low- and lower-middle-income countries. This reflects the nonlinear nature of climate impacts on agriculture and the heightened vulnerability of crop yields to temperature increases in regions where baseline temperatures are already high (Ortiz-Bobea, 2024). The largest relative decline would occur in South Asia and sub-Saharan Africa.

There are a range of climate-econometric estimates in the literature and these findings are consistent with recent work, such as by Kotz et al. (2024) and Bilal et al. (2024). The Stern review (2006) on the economics of climate change found that, without action, GDP would decline around 5% each year forever, based on market impacts, and by 11% when including the value of health impacts (Ackerman, 2007). The results of our model are in line with the Stern review, even though they are reported only for a selected terminal date (2050) due to the uncertainty surrounding future trajectories of both climate change and adaptation. They are also driven by explicitly modelling rainfall effects, made possible by better data and a more comprehensive methodology. Outcomes might appear high compared to some results in the literature. However, as demonstrated in Appendix 3.4, turning off the rainfall "channel" reduces the impacts, bringing them in line with recent studies that have used computable general equilibrium models.

Climate change and variations in total water storage

Ignoring trends in total water storage risks underestimating the economic impacts of shifting hydrological conditions. The model integrates these through supply curves that reflect changes in the availability of water resources. Figure 3.8 illustrates the combined impacts of temperature fluctuations, precipitation changes, and total water storage variations. The most significant declines in GDP and food production are observed in low- and middle-income countries, particularly in arid regions where water scarcity is already critical. Further specifics can be found in Appendix 3.4.

Figure 3.7: Changes in GDP under climate change



Notes: The whiskers depict upper and lower estimates from Monte Carlo simulations taking different parameters from the literature.

Figure 3.8: Combined impacts on GDP of climate change and total water storage variations

Lack of access to safe water and sanitation claims lives and inflicts severe losses of income. The triple burdens of rising temperatures, reduced total water storage, and lack of access to clean water forms a formidable barrier to progress. The World Bank approach to quantifying impacts on human capital and income is used to assess the magnitude of these losses. When combined with climate change and shifts in total water storage, the lack of access to clean water and adequate sanitation results in losses in GDP adjusted for human capital impacts averaging 14% as compared to the business-as-usual scenario. Table 3.1 highlights the effects of including water, sanitation, and hygiene (WASH) related losses by adjusting GDP to account for changes in human capital.[7]

The virtual water trade

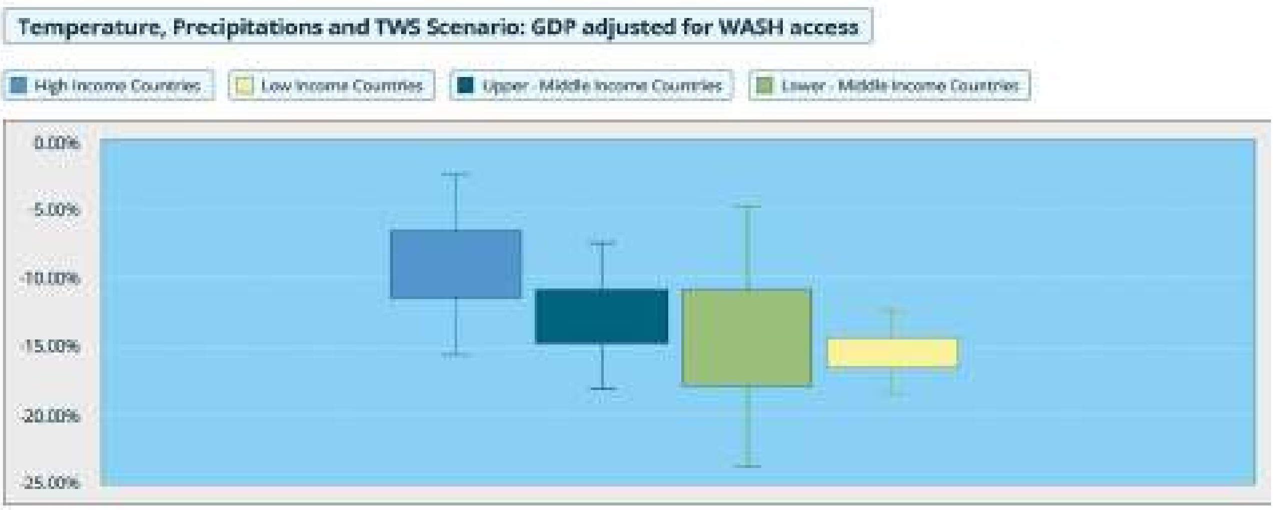
Virtual water trade refers to the exchange of goods and services based on their virtual water content (VWC), defined as the amount of water required to produce each good and service including all steps involved in its production. Virtual water has become important in assessing global trade dynamics. Approximately 1.6 trillion cubic metres of water is traded in this way. When the price of water does not reflect its value and scarcity, trade can accentuate water depletion. For instance, it takes 12 litres of water to grow a single almond, and around 80% of almonds grown in the arid United States (US) state of California are exported. Notably, Californian production and export of almonds doubled during a period that coincided with droughts and land subsidence due to over-extraction of groundwater. Similarly, production of cotton in Uzbekistan has been linked to depletion of the Aral Sea.

These examples underscore how trade can intensify water overuse and depletion. However, trade can also mitigate water-related pressures by enabling countries with abundant hydrological resources to specialise in producing water-intensive goods for export to water-scarce nations.

Table 3.1: Extended GDP losses from climate change, total water storage, and reduced WASH access

	Mean	Median	upper bound	lower bound
Lower-Middle Income Countries	-14.341%	-13.903%	-25.152%	-5.718%
Low Income Countries	-15.476%	-15.339%	-18.909%	-12.742%
TOTAL	**-14.411%**	***-13.992%***	**-24.765%**	**-6.154%**

Figure 3.9: Combined impacts of climate change, total water storage variations, and lack of wash access



7 This can be considered extended GDP losses including human capital (echoing Net National Product principles).

Estimates suggest that trading certain agricultural products saves about 300 cubic kilometres of water, roughly 5% of global agricultural blue water use (Fader et al., 2011).

Climate change and total water storage imbalances are poised to disrupt global trade by altering the costs of producing water-intensive goods. As climate change and declining total water storage trends drive up the implicit cost of water, the price of water-intensive goods rises relative to other commodities, diminishing the volume of virtual water traded. This affects agricultural production directly, leading to a global decline in the volume of agricultural commodities traded, with effects across all economic activities.[8]

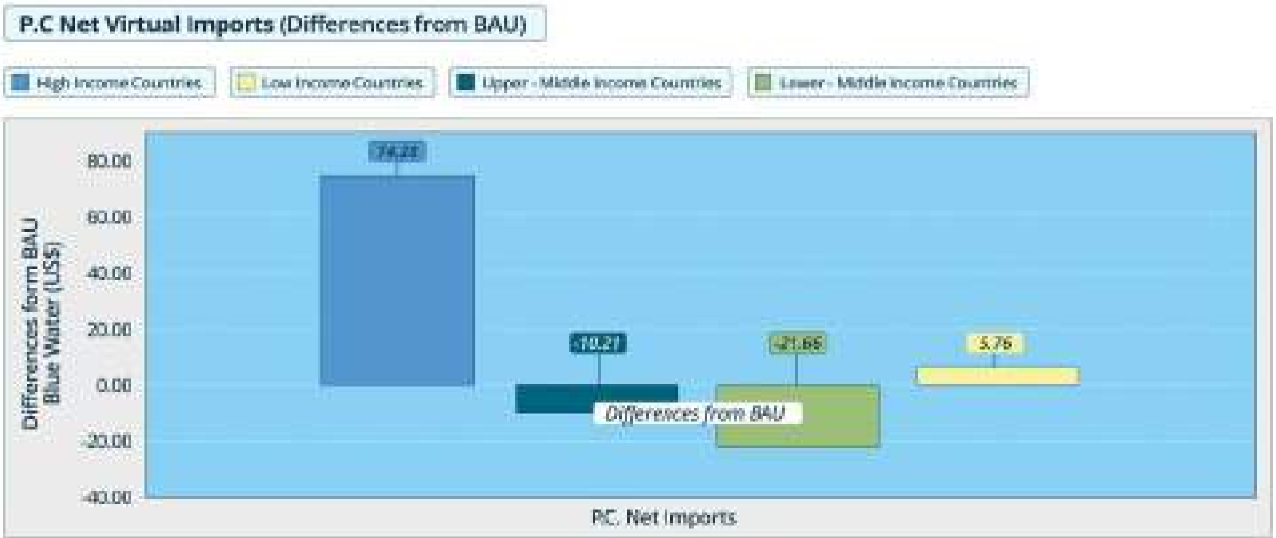
Deteriorating hydrological conditions also induce shifts in the natural comparative advantage of countries, changes in efficiency levels, market conditions and government interventions. Model simulations suggest that higher income countries reduce their exports and increase imports while the poorest countries – heavily reliant on agriculture – are negatively, but not disproportionately impacted (Figure 3.10).

When confronted with rising global prices for agriculture, countries often respond by restricting exports. The surge in rice and wheat prices has elicited such responses. Though protectionism might appear necessary for food security, it results in a uniform GDP decline, disproportionately impacting upper-middle-income countries due to altered trade patterns (Appendix 3.4). This confirms that retreating into protectionism amid supply shortages is counterproductive, leaving all parties worse off.

Reversing the decline

The economic consequences of water stress are exacerbated by policies that promote overuse and allocate water in ways that neither reflect the benefits water could bring nor consider equity and environmental sustainability. The computable general equilibrium framework offers a valuable lens through which to explore the extent to which better-aligned incentives can reverse or mitigate adverse impacts.

Figure 3.10: Changes in per capita virtual blue water trade due to deteriorating hydrological conditions



Notes: The simulations show effects from climate change and variations in total water storage. High-income countries (net exporters) show a substantial increase, suggesting reduced exports and increased imports of virtual water. Upper-middle, lower-middle, and low-income countries (net importers) experience declines in net virtual water imports.

8 The model does not consider speculative responses such as shorting or monopolising markets. It could be argued that, since most basic commodity markets are competitive, with numerous sources of supply, such attempts might not have lasting, significant global impacts but could be of a concern in smaller, regional markets not well linked to more competitive markets – though this possibility cannot be ruled out a priori.

Box 3.4. Model results compared to the literature

The effects on trade reported in the model are the differences between the model scenarios described. Under the simulated scenarios, even though growth will occur and overall trends in virtual water trade will remain positive, the water-related stresses are projected to reduce virtual water trade relative to this baseline by influencing GDP, and trade patterns. These results reflect higher water scarcity, making products based on water-intensive value chains less economically viable especially in water-stressed regions. This would not only reduce the exports of these products but contract their whole value chain in comparison to a scenario without water stress. Additionally, climate change's negative impact on GDP, particularly in agriculture-dependent, low-income countries, would diminish their capacity to produce and export water-intensive commodities.

Most literature supports the view that these combined factors will make the current trends in virtual water consumption unsustainable, which will likely lead to a contraction in virtual water trade. For example, Dalin et al. (2012) highlight that climate change might force virtual water trade to become increasingly concentrated in a few key importing countries. Konar et al. (2013) finds that water scarcity might reduce the total volume of virtual water trade. Orlowsky et al. (2014) and Sartori et al. (2017) suggest that unsustainable water consumption and reliance on exporting nations could lead to "imported water stress" for some countries. In contrast, Graham et al. (2020) project a significant increase in virtual water trade combining a business-as-usual scenario with future climate changes. These reported estimates are cumulative changes rather than a direct comparison of scenarios with and without climate change. Their results rely on the Global Change Assessment Model (GCAM), an integrated assessment model (IAM) that links various systems (energy, water, land) using a different approach and assumptions compared to those used in computable general equilibrium models to represent markets, economic agents, and trends (Gambhir et al., 2019).

Figure 3.11 illustrates the outcomes of a policy experiment where water tariffs are adjusted to reflect externalities and scarcity. GDP sees significant gains in low- and middle-income countries, which are predominantly water-scarce. Conversely, the impacts are minimal to negligible in higher-income countries, as in many cases they have more abundant water resources and economies that are less dependent on agriculture. Addressing market failures and scarcity constraints is thus pro-poor and benefits water-stressed lower-income countries more than higher-income countries. Simulations suggest that this robust finding holds even when a subset of countries introduce such efficiency pricing.

These results illustrate that improving resource allocation, whether by tariffs or other means, renders production and consumption activities more responsive to water scarcity and opportunity costs. These effects would ripple through the economy with positive feedback on water availability and long-term sustainability.

The results suggest that aligning economic incentives with water scarcity could yield a triple dividend: (1) water-related impacts of climate change are largely neutralised, improving climate resilience; (2) equity increases, since the benefits are distinctly pro-poor at country level; and (3) environmental benefits accrue, since resource depletion is ameliorated. It is rare to find such synergies.

The simulations further indicate that, while pricing water to reflect its implicit cost could improve economic outcomes, this is insufficient to eliminate economic inefficiencies related to water use. In a second-best world where the economy is plagued by other distortions, such as harmful subsidies and monopolies, addressing distortions in one sector will not be as effective while they prevail in others. For instance, pervasive agriculture or energy subsidies make appropriate water pricing less effective. Complementary interventions can amplify the economic, equity, and environmental gains in these cases: the benefits of pricing policies can be increased by eliminating subsidies in water-intensive sectors or by shifting them to water-saving technologies and approaches to address possible rebound (Jevons) effects.[9]

9 Rebound effects occur when some or all the water saved through efficiency improvements is used.

Figure 3.11: Impact on GDP of water pricing to reflect the implicit cost of water

Notes: The figure illustrates the impact of implementing a policy package focused on pricing and recycling revenues to enhance water efficiency and reduce related resource misallocation. The results suggest that this policy package significantly mitigates losses relative to the climate change scenario for lower-middle-income and low-income countries, with approximately 15% and 8% higher GDP levels, respectively. In contrast, high-income and upper-middle-income countries experience minimal changes. By addressing externalities through targeted policies, countries can achieve greater efficiency and improved resource management, especially benefiting those with economies heavily reliant on water.

Policies and pathways to improve water resource management

Current policies are not appropriate for the water challenges of the 21st Century. Unsustainable trends in water resources reflect at least in part policy deficiencies that fail to incentivise prudent management and stewardship. Water management is dominated by mechanisms such as government allocation and water-sharing rules that seldom reflect the marginal value of water and can promote wastage and overuse.

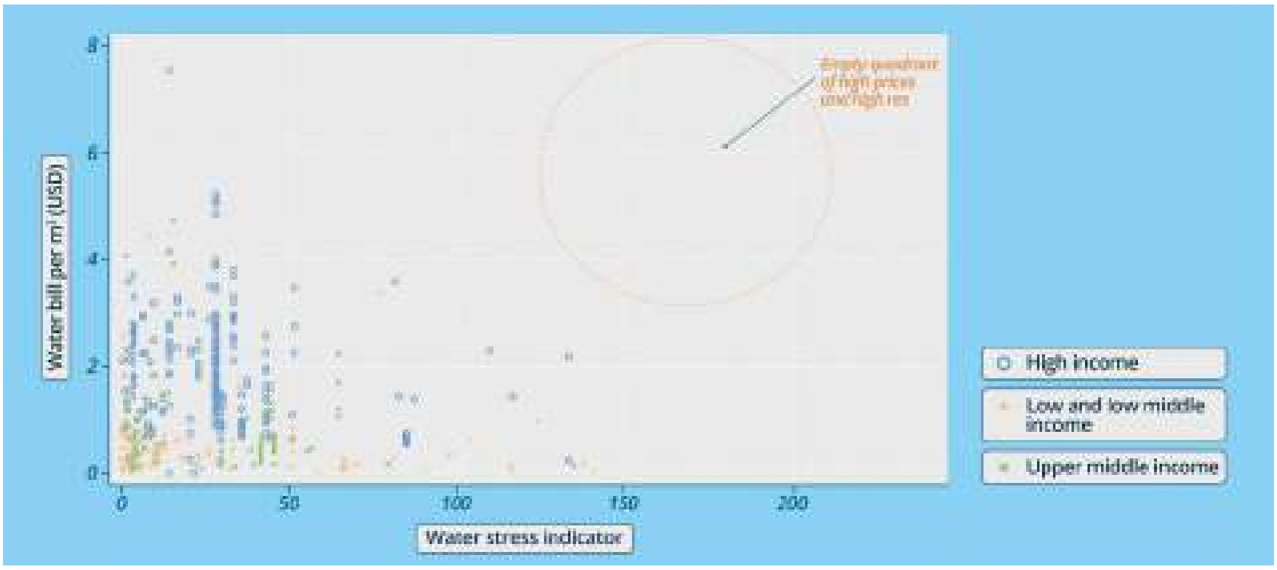
Pricing patterns are often perverse. Figure 3.12 indicates that the lowest water tariffs are frequently encountered in some of the most water-stressed nations. These do not appear to stem from concerns about equity or affordability, as some affluent countries with high levels of water stress have among the lowest water tariffs in the world. Prices in these countries reflect neither scarcity conditions nor users' capacity to pay.

Concerns about how to price water have long been debated. High prices could exclude the poor, while a price that is too low encourages profligate use and creates economic and environmental costs. Appropriate pricing typically depends on a mix of policy instruments: where safety nets exist to assist lower-income households, prices can recover the high cost of capital-intensive water infrastructure, signal scarcity, and reduce overuse and waste. In practice, this is more the exception than the rule.

The price of water is low in most settings and far below the level required to balance supply and demand. Prices in most countries are well below the range that make water-saving a financial consideration. As a result, studies find that the demand for water is price-insensitive (inelastic) at prevailing prices. In some cases – especially in the irrigation sector – low prices combine with low collection rates and offer little incentive to use water more efficiently and curb waste. Meanwhile, a concern in urban settings is tariff structures that are complex and difficult for consumers to understand. This diminishes the effectiveness of higher prices as a tool to encourage prudent water use.

Water pricing remains controversial and complex. Regulatory and economic instruments like property rights, water permits and pricing can promote better environmental stewardship, but there are valid concerns that these could exacerbate inequities. There are fears of elite capture, denial of services to the poor, and neglect of water's social and cultural significance. The success of water policies hinges on systems that embrace equity concerns rather than using this challenge to eschew attempts to incentivise more environmentally and economically prudent water use. A well-designed system would differentiate between the poor (be they subsistence farmers or city dwellers) and other users (including industries and large-scale

Figure 3.12: Country-level water stress vs. average price of water charged by utilities



Notes: Water stress is defined as the ratio between total freshwater withdrawn by all major sectors and total renewable freshwater resources, after considering environmental water requirements. This indicator is also known as water withdrawal intensity. Main sectors as defined by ISIC standards include agriculture, forestry and fishing, manufacturing, electricity, and services.

farms) who have greater capacity to pay. Various policy options can address affordability concerns: targeted cash transfers and subsidies (facilitated by digital technologies) can support poor households; free or subsidised water can serve as a safety net; and free water connections for the poor in urban areas can reduce reliance on informal vendors.

Conversely, commercial users, including industries and large-scale farms, typically have a higher ability to pay. Charging rates that reflect the true opportunity cost and scarcity of water can incentivise improved allocation and more judicious use of water. However, current policies often do the reverse. Underpriced water and industrial policies in "priority" sectors encourage water-intensive industries to locate in some of the most arid parts of the world.

Water for agriculture

Agriculture, the principal consumer of blue water globally, exerts a strong influence on the availability and sustainability of water resources. In most countries, water is allocated to farmers through rationing and sharing rules. The design and evolution of these often mirror water availability, legal traditions, and community norms, which may lag behind rapidly changing hydrological and socioeconomic conditions. Such systems are particularly crucial where water is scarce.

In regions where water is plentiful, as in much of the eastern US, riparian doctrines permit unrestricted use rights to lands adjoining waterways. Conversely, in the arid western US, water rights have been decoupled from land to facilitate investment in irrigation (Leonard & Libecap, 2019). In the Middle East, where water is typically scarce, *aflaj* water systems define rights as time-based shares rather than absolute quantities. This implies that shortages are shared proportionally as flow rates diminish (Bandyopadhyay & Mershen, 2022). In some parts of Latin America, *acequias* rights are allocated to individuals based on the volume extracted. Each allocation system specifies how shortfalls are distributed during times of scarcity.

Each of these systems addresses specific problems but brings challenges of efficiency, equity, and environmental sustainability. Proportional sharing rules such as *aflaj* and *acequias* maintain higher crop yields than a seniority allocation (Gómez-Limón et al., 2021; Ji & Cobourn, 2018), but they are also inefficient, as sharing leads to overcapitalisation and therefore overuse of water (Smith, 2021).

Sharing rules that prioritise certain users, such as seniority allocation, generate inefficiencies when junior users are more productive (Bennett, 2000). The most striking example is urban water, which holds junior water rights in the western US, but serves many more people and generates multiple times more social and economic returns than irrigated commercial agriculture.

Of even greater concern is the vulnerability of administrative allocation schemes to rent-seeking and political influence, with perverse distributional consequences (Wade, 1982). Resource capture and the fate of poorer farmers at the tail-end of irrigation canals have been widely documented (Jacoby et al., 2021), but there is limited empirical research due to the clandestine nature of corruption.

Despite the magnitude of water use in agriculture, information on the prices charged to farmers for irrigation services is fragmented and unreliable, and almost non-existent in developing countries. What information exists suggests that irrigators pay a small fraction, if any, of the water price charged to urban users (Cornish & Perry, 2003). Surveys of developed countries conducted many years ago by the OECD (2010) provide an indication of pricing patterns and trends that likely remain relevant. OECD economies aim for cost recovery, but few attempt to price irrigation water to manage demand or address environmental externalities. Wealthier OECD countries have largely achieved full recovery of annual operating and maintenance costs, and partial recovery of capital costs. There is a wide range of pricing mechanisms used even within a country (Cornish et al., 2004). Some cases use volumetric charges while others base them on farm size or factors unrelated to water use.

Information for developing countries is even more limited and unreliable. The only available and partial survey, conducted by the World Bank in 2020, finds that 94% of the 38 countries covered do not recover any operation and maintenance costs (Damania et al., 2023). Water is effectively supplied free in most cases, often treated by governments as a form of social security. Consequently, larger and wealthier farmers capture most of the benefits, deepening inequalities.

The magnitude of direct and indirect subsidies accruing to water users in agriculture is vast, likely far exceeding USD 0.5 trillion. Water users benefit from the use of free or underpriced water, the extent of which is unquantified. They benefit from subsidies to the agricultural sector, estimated to exceed USD 630 billion per year (OECD, 2023).[10] More than 60% of these are coupled with production, implying that farmers receive support for buying specific inputs or growing specific crops. This distorts farmers' decisions, reducing productivity and causing harmful environmental spillovers such as deforestation, polluted waterways, and depleted water supplies – often beyond national borders. In particular (Damania et al., 2023):

- Subsidies to rice, cotton, and sugarcane encourage cultivation of these water-intensive crops in some of the most arid parts of world, like the Middle East and South Asia, thereby accentuating water stress. In Australia, irrigators who received an irrigation infrastructure subsidy increased their water extraction 21–28% compared to those who received no subsidy (Wheeler et al., 2020). In Peru, subsidising improved irrigation for poor farmers led to extensification of agricultural land without improving farming efficiency.

- Agricultural areas around the world risk losing up to 13.2 km^3 of groundwater per year due to distorting subsidies – roughly equivalent to the water lost over the five-year drought in California from 2011 onwards.

- Agricultural price supports are responsible for the loss of 2.2 million hectares of forest cover per year – approximately 14% of annual deforestation – which disrupts moisture recycling and precipitation patterns.

- The impact of subsidies is not constrained by national borders: agricultural subsidies in some countries drive tropical deforestation around the world. For instance, livestock subsidies in the US drive deforestation in Brazil by increasing demand for soybeans for feed.

- Nitrogen fertiliser, an essential input in commercial agriculture, is heavily subsidised and thus overused in much of the world. This accounts for about 17–20% of the nitrogen leached into water, which results in water-body hypoxia (dead zones where nothing survives), can cause lethal "blue-baby" syndrome in infants and correlates with higher

10 Transferred to individual producers during 2020-22. https://www.oecd.org/en/publications/agricultural-policy-monitoring-and-evaluation-2023_b14de474-en.html

occurrences of colorectal cancer and thyroid problems,[11] and has transgressed the safe planetary boundary (Schulte-Uebbing et al., 2022). Other inputs such as pesticides are also subsidised, though there is insufficient data on the magnitude of these.

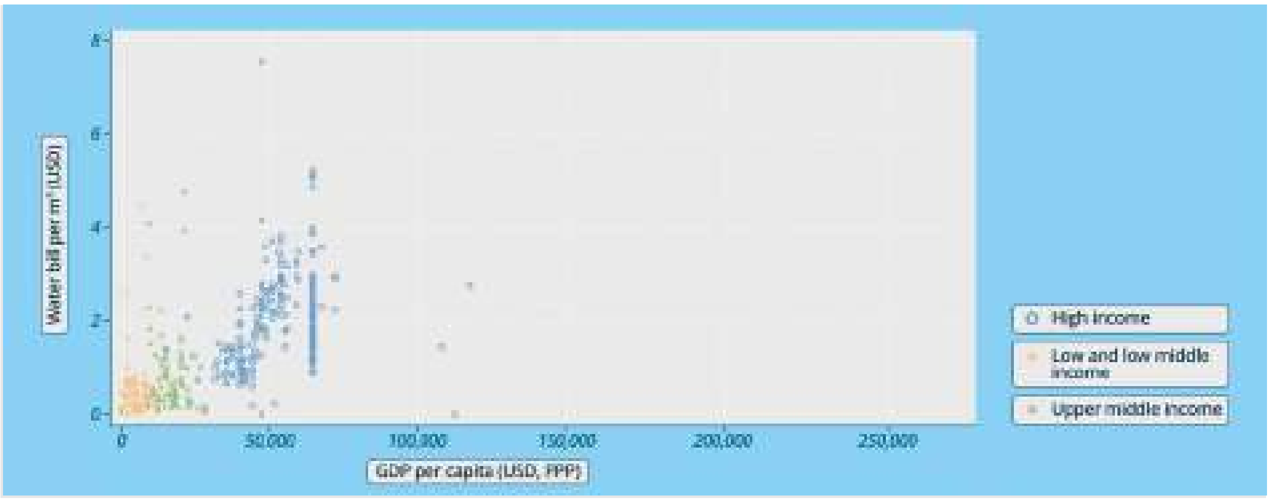
Municipal water

There is more information available in the municipal sector as part of global efforts to monitor water-utility performance. Available data[12] are incomplete and unrepresentative, but still indicative of the extent of pricing and practices. Figure 3.13 shows vast variation in the average prices charged for municipal water services. In general, utilities in higher-income countries set higher prices, reflecting both higher labour costs and a greater willingness to pay that affluence brings. Notably, small island economies, which confront high supply costs, also tend to have higher charges, irrespective of income levels. Countries with low prices recover neither operation and maintenance costs nor capital costs, and depend on government subsidies to cover financial deficits. While these might be well-intentioned, they bring unintended consequences. Poor tariff design can undermine equity objectives, rendering subsidies expensive, poorly targeted, and distortionary (Andres et al., 2014). Figure 3.14 shows that subsidies are common across countries, irrespective of region or income. They are expensive – estimated at around USD 300 billion annually – with a mere 6% of the benefit accruing to the poorest 20% of the population (Andres et al., 2014). Finally, by weakening the link between consumption of water and the cost of providing it, subsidies promote overuse.

In low-income countries with limited fiscal space, a reliance on subsidies will often mean that universal access to water is unaffordable. Thus, low prices result in limited access to piped water and sanitation services. In such circumstances, poor households who do not have connections must obtain water as best they can from traditional sources, water vendors, or public taps on the piped distribution system. As a result, unconnected households pay far more for water than rich, connected households in either money, time, or both (Pattanayak et al., 2005). Further, lack of access to safe water services is associated with a host of water-related diseases. Globally, 2.2 billion people lack access to safe water and 3.4 billion do not have access to a safe toilet (WHO/UNICEF, 2023).

Further complications arise from the natural-monopoly characteristic of water supply infrastructure. The most cost-effective way to supply water to consumers is through a single pipe, which in turn must have a single owner—a natural monopolist. This brings the risk that water suppliers (utilities) will leverage their monopoly power by inflating costs or raising prices. However, simple pricing rules that aim to recover costs without considering the scope for cost inflation would incentivise waste and condone inefficiencies.

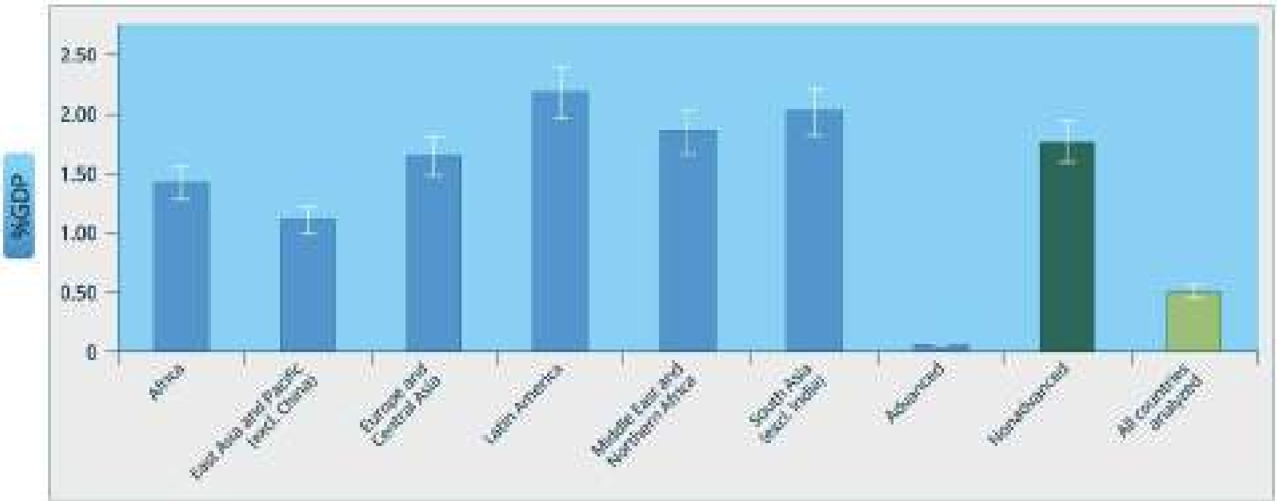
Figure 3.13: Average water price and GDP per capita



11 Excess nitrogen runoff from fields ends up in drinking water. Once water is contaminated, denitrification is a costly process.

12 The data is from IBNET, a World Bank and Global Water Intel initiative. There is likely a consistent bias in this data with utilities submitting data in years of good performance. This leads to potentially severe attenuation biases that should be noted in interpreting the data.

Figure 3.14: Estimated water supply and sanitation subsidy as a percent of GDP by region



Source: Andres et al., 2014

In general, around 28% of public funds allocated to the sector go unspent, and a typical water utility experiences efficiency losses averaging USD 21 million, equivalent to 16% of operating costs (Joseph et al., 2024). These inefficiencies result in substantial hidden costs, likely amounting to hundreds of billions of dollars globally. Addressing this problem calls for strategies that balance the interests of the monopolist (whether private or public) against wider public policy goals.

Three principles for achieving efficiency, equity, and environmental sustainability

Current water policies are unable to address the challenges of the Anthropocene, resulting in an unacceptably high human and economic toll. This suggests the need for a significant shift in water governance policies, guided by three overarching principles: (1) value water for the essential services it provides; (2) establish absolute limits to ensure its sustainability; and (3) develop policy packages to promote synergies.

Principle 1: Value water for the essential services it provides

The failure to value water and acknowledge its economic, environmental, and societal contributions remains a significant obstacle to progress and the implementation of the United Nations (UN) Sustainable Development Goals (SDGs). Water is rarely priced in ways that reflect its scarcity and contribution. Thus, it is used wastefully and seldom allocated to its most beneficial uses.

Improved allocation could be achieved through infrastructure and regulations (top-down command-and-control approaches), and economic instruments such as pricing and trade. Under any policy regime, safeguards would need to assure access for poor households and environmentally sustainable and prudent uses, as shortages typically create "rents" that are vulnerable to capture.

Economic instruments can be powerful mechanisms to promote better water management, but face resistance from users accustomed to subsidised water. Recognising that good economics is not necessarily good politics, approaches now being piloted are better aligned with the incentives and constraints of decision-makers. For instance, experience suggests that price reforms, such as the elimination of environmentally harmful subsidies, are more likely to gain public acceptance when accompanied by compensation and safety nets that protect the poor and marginalised populations.

Principle 2: Establish absolute limits to ensure sustainability

Acknowledging that blue and green water are both generally renewable but also finite resources implies that there are absolute limits to the amount of water that can be consumed safely and sustainably. As suggested by Barbier (2022), acknowledging that the economy is embedded in the biosphere implies that there are absolute limits to the extent to which resources, that have no close substitute, can be sustainably used. This has implications for the management of critical natural resources (Sureth et al., 2023).

For blue water, this will mean determining explicit limits on the amount of water withdrawn, and limits on pollution concentrations. Water-stressed regions might need to realign their economies and produce goods that better reflect their natural resource endowments and comparative advantages. Trade in virtual water will be critical to easing supply constraints and decoupling consumption of water-intensive goods from their production. Virtual-water trade can also lead to efficiency and water savings if trade in water-intensive commodities flows from regions with high water resources and high productivity to regions with lower water productivity.

For green water, absolute limits will involve protecting forests and wetlands as the sources of terrestrial moisture supply, will require policies and incentives to conserve soil moisture, which holds around 60% of terrestrial rainfall. Thus far, scalable solutions have remained elusive as the forces of deforestation are powerful and deliberate, while conservation policies have been less effective and slow to react. It is unlikely that small adjustments to current policymaking will solve this sustainability challenge, suggesting the need for bold targets and ambitious reforms.

Principle 3: Develop policy packages to promote synergies

No single policy can achieve the goals of efficiency, equity, and environmental sustainability at once. Policy packages will need to address the trade-offs likely to emerge. For instance, higher water prices might promote greater efficiency but disproportionately impact the poor, calling for compensation to achieve equity goals. Policy packages will also need to address distortions that originate outside the water sector and can stymie reforms within it. For example, subsidies to water-intensive crops or industries directly undermine the ability of water prices to regulate demand.

Innovations in blue water management

Recent empirical and experimental evidence provides valuable lessons about the effectiveness of different approaches attempted to promote more efficient, equitable, and sustainable water management. A critical takeaway is that in "second-best" scenarios characterised by multiple distortions, concentrating solely on the water sector can lead to suboptimal outcomes and potentially unintended repercussions. Additionally, these strategies are noteworthy for acknowledging implementation hurdles, transactions costs, and the constraints and motivations that drive decision-makers.

Volumetric incentives and pricing

While pricing incentivises more efficient and judicious use of water, introducing water prices in the agricultural sector has often involved political and logistical challenges. The transactions costs of pricing can be considerable in developing countries, where irrigation is practiced by large numbers of small-scale users. Moreover, irrigation pumps are typically not metred or metres that are installed are not tamper-proof. In such settings, enforcement and billing can be logistically difficult. Hence several alternative approaches are being piloted across countries.

A vast literature finds that the subsidisation of water leads to overuse and waste (Barbier, 2015). Repurposing poorly designed subsidies yields multiple benefits in promoting efficiency, expanding water-related services, and improving equity (Trimmer et al., 2022). The lessons learned from past subsidy and policy reform efforts converge on three keys to success: (1) compensating those who lose and would resist reform; (2) communicating to build coalitions of support; and (3) charting a credible reform strategy that will not be reversed. Generally, pricing water used by small-scale and low-income farmers would need to be accompanied by appropriate safety nets and alternative forms of support. One such approach involves shifting direct water subsidies and implicit subsidies inherent in the provision of free water into compensation that combines water billing with direct monetary transfers to users.

There is a trend towards new, field-tested alternative approaches that could achieve some of the same benefits as pricing while circumventing the political obstacles. While such approaches might only offer less-effective “second-best” solutions, they could be the only feasible options. One recent innovation makes cash transfers conditional on the verifiable adoption of water-saving practices, such as shifting cultivation to less water-demanding crops. The effectiveness of such programmes is worth evaluating. The literature also provides guidance on how to test for leakage and additionality.

The use of water and the energy to pump it are often intertwined. This nexus can generate opportunities to save both water and energy through more efficient use. Energy prices for pumping can be used to internalise the scarcity cost of water to some degree, and power rationing can limit water extraction. However, it can also make energy subsidies lead to excessive use of water. In India, power for pumping groundwater is often provided at low or zero rates, which is thought by many to exacerbate excessive groundwater pumping. Here too, these challenges call for the development and testing of creative ways to generate indirect price-like incentives. For example, programs were proposed that incentivised farmers in India to voluntarily reduce power use for pumping groundwater below a given benchmark, with a volumetric incentive reward. Such an approach creates conservation incentives that benefit farmers and circumvent political resistance. Pilots in India's Gujarat and Punjab provinces produced mixed evidence of the impact on pumping rates. Regardless, additional approaches should be considered and evaluated through field experiments in diverse settings.

There is wide acknowledgement that formal and informal water markets tend to improve efficiency by reallocating water toward uses that are more highly valued, which can be a useful risk-management tool for farmers – though there might be distributional and environmental concerns that warrant safeguarding (Nauges & Wheeler, 2024). Water markets allow farmers to adapt to changing circumstances through water reallocation in response to seasonal conditions. Since they involve voluntary exchanges between sellers and buyers, they reflect the real opportunity costs of water to users.

However, less than 1% of freshwater withdrawn worldwide is traded on markets (Rafey, 2023). This might reflect the high transaction costs of establishing official water markets. Formal water markets require onerous conditions – such as adequate legal and governance structures, costly infrastructure to transfer water from buyers to sellers, and enforcement mechanisms – and hence are limited to developed economies, as in Australia, China, Chile, Spain, and the US.[13] Meanwhile, informal water markets seem pervasive, especially in Asia. But there has been resistance to water markets from those who view water as a resource too valuable to trade (Bakker, 2007). Experience also suggests that markets might bring risks associated with rent capture, imperfect competition, and severe environmental externalities. However, these obstacles are not insurmountable and can be overcome with appropriate market design and trading rules.

Supply-side policies and the paradox of supply

Systematic economic forces can cause the best-intentioned policies and investments to fail. The history of water infrastructure abounds with such instances of policy disappointments.

13 In Australia and the US, water-management institutions have the option to purchase water entitlements from willing irrigators and the purchased water is, in part, used to restore natural assets (Pérez-Blanco et al., 2023). This public reacquisition of water is known as buyback (Rey et al., 2019).

Historically, water scarcity has been managed through infrastructure interventions, such as water storage and the transfer of water within and across river basins. But when supply is increased without corresponding incentives and safeguards to manage use, demand rises to meet the new level (Hornbeck & Keskin, 2014; Zaveri et al., 2020). The provision of free water signals that it is economically abundant when, in fact, it is physically scarce in arid areas. Farmers respond to economic signals rationally by using more water, amplifying the impacts of water scarcity – an example of the 'paradox of supply'.[14]

Encouraging the adoption of water-saving technologies

Another approach to improving the efficiency of water use is the dissemination of water-saving or water-efficient practices and technologies. Adoption of these can be encouraged through subsidies or informational campaigns. One example is the Indian government's Pradhan Mantri Krishi Sinchayee Yojna (PMKSY) program, which offers substantial subsidies for the purchase of micro-irrigation such as drip and sprinkler irrigation.

The adoption of improved technologies can be hampered by a range of constraints and market failures, especially but not only in developing countries. There is a need for policy intervention to boost technology adoption, especially where these confer external benefits.

Programs that subsidise the adoption of resource-saving technologies are criticised on several grounds. First, they might reward users who would have adopted the technology even without the subsidy – i.e., fail to achieve additionality – and might be subject to elite capture or disproportionately benefit socioeconomically better-off farmers. Second, when they are not accompanied by price signals or constraints on the use of the resource, adoption of the technologies might have rebound or Jevons effects. Additional evidence is needed to determine the package of policies needed to address these issues.

Achieving the 3Es calls for recognising the power of economic incentives to generate benefits from the use of water, address the risks that arise from water stress and correct externalities such as water pollution. It also calls for complementary approaches that shift from a focus on fixing problems after the damage has been done, to avoiding problems from occurring in the first place. Prevention is typically more cost effective than the cure, which suggests the need to shape markets to use and allocate water more efficiently, equitably, and sustainably from the start.

14 It is possible that cultural norms could override economic incentives, though this seems to be less widely observed.

4. Pushing the economics: The case for shaping markets

Key takeaways

Markets must be shaped by governments and other actors to become more efficient, equitable, and environmentally sustainable. The current system treats our biggest challenges – climate change, inequality, the lack of clean water – as failures of an otherwise sound system, even though these challenges are embedded in the way global economies operate. We must shift our economic framing from fixing externalities after-the-fact to proactively shaping economies so that water is allocated efficiently, equitably, and sustainably from the start. Markets across our economies – from agriculture and mining, to energy and semiconductors – must be reshaped in their water use and impact on the hydrological cycle, using outcomes-orientation and directionality.

Governments must adopt a mission-driven approach to policymaking, bringing multiple sectors together to tackle the global water crisis in an economy-wide way. Missions are ambitious, clear, and time-bound objectives that mobilise cross-sectoral solutions to difficult challenges. They focus on outcomes, as opposed to outputs, and in doing so, missions can target challenges that do not necessarily have pre-defined, technological fixes. Solving these therefore requires a bottom-up approach, exploring many possible solutions and mobilising economy-wide innovation, investment, and partnerships. This approach is adaptive, cross-sectoral, inclusive, and firmly committed to economic efficiency, justice and sustainability.

Justice and equity must be at the centre if we are to solve the global water crisis (Gupta et al.,2024). The common-good approach and a framework for Water System Justice can help governments shape markets so that blue and green water is managed in a fair and sustainable way. Taking justice and equity seriously ranges from including voices of local communities and the most vulnerable, to embedding justice- and equity-based values in partnerships and contracts.

We need to revise our assessments for how much water humans need for a dignified life. Taking an economy-wide approach and factoring in other needs for human development, such as food and industry, as well as blue and green water supplies, presents a far higher integrated estimate of freshwater needs for a dignified life. The GCEW recommends increasing the minimal water requirements from 50 to 4,000 litres/person/day.

Managing water efficiently, equitably, and sustainably as an economic good requires a new set of economic principles for water governance. Chapter 3 introduced three overarching principles: (1) value water for the essential services it provides; (2) establish absolute limits for the amount of water that can be safely and sustainably consumed; and (3) develop policy packages to promote synergy, because no single policy can achieve the competing requirements of efficiency, equity, and environmental sustainability.

To ensure these priorities lead to the systemic, collective, and economy-wide action demanded by the global water crisis, they must be underpinned by a new economic framing that is less reactive and more proactive. Water economics must be rethought so that we shape markets from the start instead of waiting to fix them after they fail. This means we need to begin by identifying the outcomes we want to achieve with a view to tackling the global water crisis and work backwards through what this means for the economy and its components – innovation, partnerships, finance, and the governance of utilities and data. Designing justice and equity into these components cannot be an afterthought but needs to be a condition for achieving desired outcomes. This chapter investigates a new economic framing based on shaping markets, designing policy with outcomes- and mission-orientation in mind, and embedding justice at the heart of our policy response.

From fixing markets to shaping economies

Much of the discussion of the economics of water focuses on the role of externalities, with sustainability and justice concerns explained as market failures (Mazzucato, 2024; Hess and Ostrom, 2003). Goods and services with positive externalities might not draw enough private investment, as not enough of the returns can be captured in the returns. On the other hand, negative externalities such as pollution require regulatory measures such as environmental impact assessments, water quality standards, punitive actions, and mechanisms to internalise the costs, such as putting a social-cost price on carbon or taxing profligate water use in dry areas.

Instead of waiting for externalities to arise and markets to fail, then intervening after the fact (ex-post), the market system can be shaped differently from the start (ex-ante) to minimise externalities and failures. This means shifting from an outsized focus on correcting externalities via redistributive mechanisms like taxes, to a focus on pre-distributive mechanisms by rethinking the market structures that lead to externalities; there is a role here for the adoption of priority of use of environmental impact assessments, emission standards, and pollution permits.

Conventional economic theory assumes that once the sources of market failures have been addressed – a monopoly reined in, a positive externality subsidised, or a negative externality taxed – market forces will efficiently reallocate resources, enabling the economy to follow a path to efficiency.

However, markets are outcomes of how economic actors, including governments and businesses, are governed and interact (Mazzucato and Ryan-Collins, 2022). Shaping markets requires starting with an objective, and designing property rights, partnerships and financial structures to deliver on that objective in a pre-distributive way from the start. This requires attention to contract design and the form of partnerships between actors. It requires moving from an ex-post lens to an ex-ante one. If not shaped with efficiency, equity, and environmental sustainability, markets can deliver sub-optimal outcomes.

Efficiency should be thought of in dynamic terms. Opportunities for innovation around water

challenges must be understood not in terms of short-run costs but of long-run investments that can catalyse economy-wide benefits and hence dynamic (versus static) efficiency gains. This requires understanding increasing returns to scale, where cumulative investments generate learning and innovation, leading to cost reductions.

Equity and justice can be put at the centre of how public and private actors invest. Otherwise, if not actively shaped, markets can create and exacerbate the existing system of property rights, and encourage hoarding and monopolisation of scarce resources, allowing some to buy up land, thereby accessing green and blue water (Bosch and Gupta, 2023). They can neglect societal or environmental concerns. Mining, energy or semiconductor companies, even farmers have no reason to use less water than they have available, or to pollute less. The past century has seen around a 600% increase in freshwater withdrawals worldwide; and water pollution has aggravated water scarcity in 2000 sub-basins worldwide (Wang, Nature 2024).

In other words, in the absence of adequate regulation, the economic system that aims at maximising returns on investment, profits, and GDP moves along a water-intensive path, taking as much water as it can and potentially polluting it without regard for water needs across social, economic, cultural, and ecological contexts. This is not just about externalities – it is about getting stuck in the wrong kind of market. It is also inherently about justice.

Further, the conception of states as a market-fixers has led to the idea that governments are not supposed to steer the economy, but only enable, regulate, and facilitate it. This has exacerbated inequalities and injustices worldwide: in low-income countries, water can cost individuals as much as 45% of income, compared to as little as 0.1% in high-income countries (see life stories reported in WaterAid, 2016).

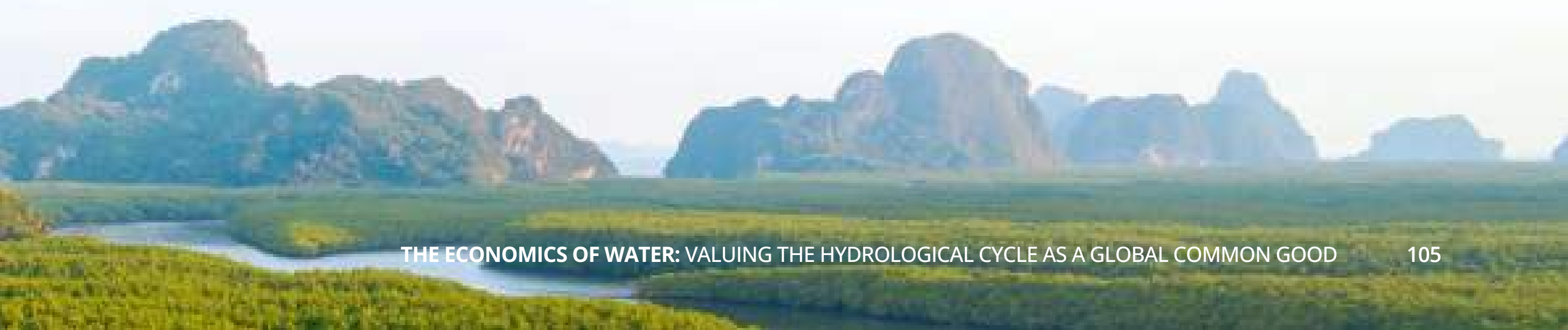
Industrial strategy (actions taken by states to shape how economies are structured and grow) can be an engine for sustainable and inclusive economic growth only if it shifts focus from sectors to missions (Mazzucato et al., 2024). To avoid mistakes of the past, a mission-oriented approach to industrial strategy would not pick winners (sectors) but missions that all sectors are required to tackle. A well-designed, mission-oriented industrial strategy can transform water challenges into opportunities for cross-sectoral innovation and investment. This can boost business investment and lead to jobs and growth that serve the interests of people and the planet.

From ex-post to ex-ante measures

The paths that economies follow under free-market conditions are problematic, particularly in the face of manifold crises, including the risks of rising sea levels, drought, floods, conflict, youth unemployment, obesity, aging, cyber security and inequality, to name a few. In these situations, states must lead by actively shaping and co-creating markets, even as they continue to regulate existing ones (Mazzucato, 2013).

A market-shaping approach means governments can shift their focus from ex-post redistributive mechanisms – like allocating water from those who have too much to those who do not have enough – to ex-ante pre-distributive mechanisms – like changing who has access to water from the start. For example, instead of taxing water used by semiconductor manufacturers in dry areas, governments can play a more important role in determining where semiconductor manufacturers produce, so that they do not have to solve the problem later.

Big, transformative changes in the world are seldom the result of market forces alone: they are



largely the result of public policies and strategic investments. From the internet to the renewable energy revolution, nearly all major technological shifts start with the public sector. Even the iPhone, often heralded as an example of market-driving innovation, relies on the government investments that led to the internet, on GPS technology developed by the United States (US) military, and on touchscreen technology first conceived in a publicly funded lab at the University of Delaware.[9]

Singapore offers a good example of shaping water markets (Leong and Li, 2017). Being amongst the most water-stressed countries in the world, Singapore has sought solutions to overcome freshwater scarcity by virtue of its geography, including building up its environment and water industry. In 2006, with water and environmental technologies identified as a key growth industry, SGD 670 million in public funds were secured to foster technologies and create a thriving research community over 15 years. As of 2024, Singapore has over 180 water companies and more than 20 water research centres. Singapore's National Water Agency (PUB) continues to facilitate private and public sector collaboration on research and development (R&D) projects, such as enabling firms to test technologies at PUB's facilities under actual site conditions.

This example shows that states have an arsenal of instruments to shape markets and should seek to use the full range of them where beneficial. In managing blue water, these tools include supply-side policies like providing strategic direct investments to support the construction of reservoirs or damns, or regulation to ensure water recycling and reuse. They also include demand-side policies, like public procurement, requiring water footprint disclosures from vendors, and only buying from those who meet sustainability standards, or being the first buyer of a cutting-edge water-saving technology such as water-recycling systems. As Chapter 3 shows, policies to manage blue water efficiency have a chequered history, and must be designed and implemented with care.

Governments also have policy instruments to manage green water. These instruments often pertain to policy domains beyond water management, making it important to adopt an all-of-government and economy-wide approach. For instance, in the context of land planning (for urbanisation, extension of agricultural land, or building infrastructure), governments can define zones where ecosystems are protected and encroachments are banned. Land-planning instruments can be used in the management of evaporationsheds to maintain vapour flows. Where properly designed and enforced, labels and certification schemes can be used to shape and direct markets away from goods that can affect ecosystems that sustain evapotranspiration.

Outcome-orientation and missions

Government policy for blue and green water management requires a direction because countries must actively change their patterns of water allocation and consumption to tackle the global water crisis. Shaping markets provides governments with the justification to use policy to change water allocation, consumption, and other drivers that tilt the hydrological cycle. Outcome-orientation indicates the direction of travel.

Distinguishing between outcomes and outputs is important to evaluate the success of market-shaping policies. *Outputs* are the tangible products or activities resulting from a project. In the case of blue water, this might include the construction of infrastructure like latrines or water treatment plants, while in case of green water, this might include planting trees in the Amazon rainforest to preserve precipitation patterns. *Outcomes* refer to the broader, long-term effects of these outputs, focusing on the real-world changes they bring, such as improved public health or increased access to clean water. Focusing solely on outputs without considering outcomes can lead to projects that deliver infrastructure but fail to achieve meaningful, sustainable improvements in water and sanitation access.

Chapter 5 examines a new approach to water governance: a mission-centred approach that operationalises market-shaping, based on directionality and outcome-orientation (Mazzucato, 2018, 2019, 2021; Box 4.1). Missions are ambitious, clear, and time-bound objectives that mobilise cross-sectoral solutions to challenges. They focus on outcomes, as opposed to outputs. By doing so, missions can target challenges that do not necessarily have pre-defined, technological fixes. Solving these requires a bottom-up approach, exploring many possible solutions and mobilising economy-wide innovation, investment, and partnerships.

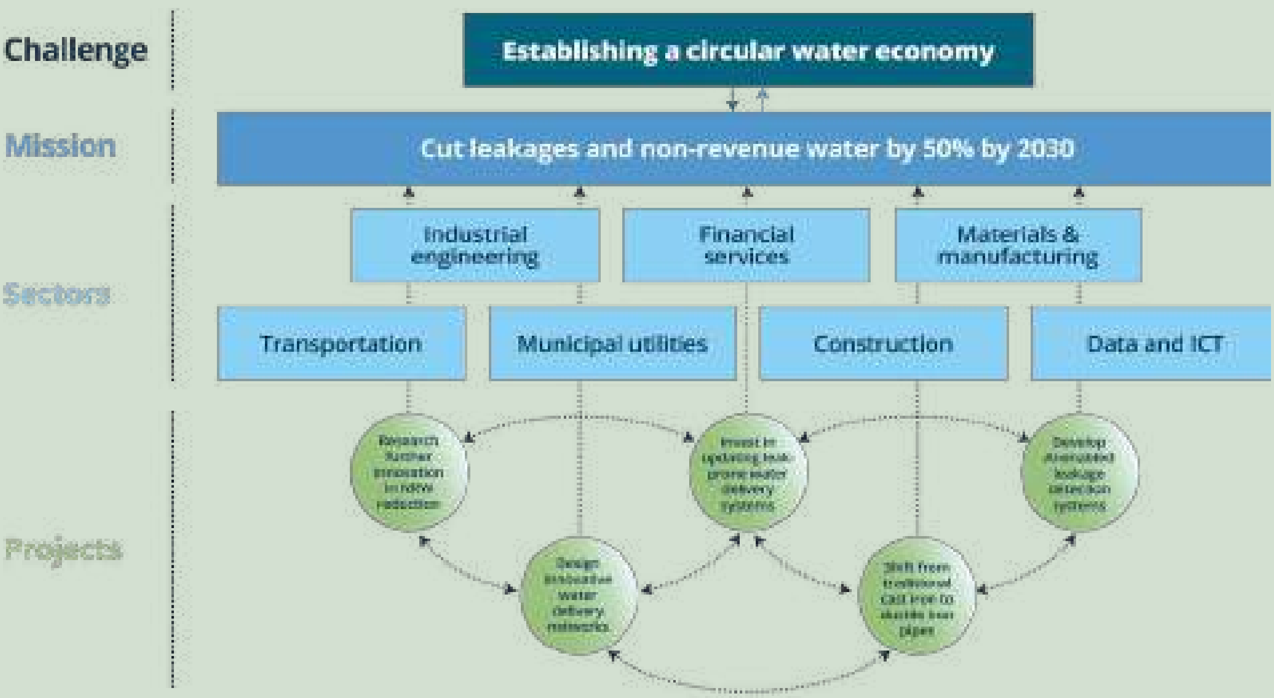
Box 4.1: Elements of a mission-centred approach and mission maps

A mission-centred approach, as detailed in Mazzucato (2018, 2019, 2021), has five criteria:

1. ***Be bold and inspirational with wide societal relevance.*** *Engage the public by demonstrating that ambitious actions and solutions will have an impact on people's daily lives.*
2. ***Set a clear, targeted, measurable, and time-bound direction.*** *Provide a framework and specific targets, whether binary (e.g., providing water, sanitation, and hygiene access to all) or quantified (e.g., increasing water efficiency by a certain percentage).*
3. ***Be ambitious yet realistic****. Set mission objectives that are centred on innovation, considering the feedback effects between basic and applied research.*
4. ***Encourage cross-disciplinary, cross-sectoral, and cross-actor innovation****. Frame missions to stimulate activity across and between scientific disciplines, industrial sectors, and actors, incorporating epistemic justice.*
5. ***Involve multiple, bottom-up solutions.*** *Allow for diverse approaches, avoiding reliance on a single development path or technology.*

Mission maps can help policymakers visualise the different components of missions and how they interact. The illustrative mission map below is adapted from Mazzucato (2018) and based on the mission of creating a circular urban water economy, as elaborated in Chapter 5. One mission to tackle this challenge could include reducing water leakages in urban areas 50% by 2030. Currently, about 40% of urban water supply globally is lost through pipeline leaks, costing USD 39 billion annually and generating significant CO2 emissions (GCEW 2023a; Burke et al. 2023). Reducing these losses will save money and resources. Innovations such as leak-resistant materials and sensor technologies for early leak detection are essential to achieving this goal.

Figure 4.1a: Mission to establish a circular water economy.



Focusing on outcomes is critical for water-related challenges because water is not a sector, as underscored in Section 4.1. Water policies must be economy-wide and cross-sectoral. Indeed, a mission around reducing water consumption in agriculture while enhancing crop yields and farmers' incomes can include sectors as diverse as agriculture, digital services, financial services, and construction.

Embedding outcomes-orientation and directionality in government policy means that all instruments and tools, such as those mentioned in Section 4.2.2, should be designed to deliver the relevant outcomes (Mazzucato & Kuehn von Burgsdorff, 2024). Part 2 of this report examines the innovations, partnerships, financing, utilities, data, and global governance required to achieve the five overarching missions. Each policy area will consider how to align concrete policy tools and public institutions with the missions in an outcome-oriented way.

Putting water justice at the centre of shaping markets

The hydrological cycle seen through the lens of a global common good requires not only outcomes-orientation and market shaping, but also a new perspective on justice. As discussed in Chapter 2 we use the common good approach for three reasons. First, water connects communities across borders and even continents, including through atmospheric moisture flows. Second, the planet has entered a vicious cycle in which the interaction of the water crisis, climate change, and the loss of biodiversity exacerbate one another. Third, the water crisis impacts virtually every one of the United Nations (UN) Sustainable Development Goals (SDGs) and threatens people everywhere: insufficient food for a growing world population, accelerated spread of disease, and increased forced migration and cross-border conflicts are some of the predictable outcomes. As a result, countries need systemic, collective, and economy-wide action to tackle the global water crisis.

In shaping markets to become more equitable and just in their water allocation and consumption, a common good lens pays attention not only to the outcomes being sought but also to how the actors in the system work together to deliver those outcomes with justice and equity at the centre (Mazzucato, 2024).

The innovation (Chapter 5), partnerships and collaborations (Chapter 6), and financing (Chapter 7) must therefore be designed in a way that recognises the contributions of different economic actors and shares the benefits more equitably. The governance of institutions such as water utilities (Chapter 8) should be done in a way that aligns with the missions, while ensuring that transparency is baked into the whole process, so that governments, businesses, and other economic actors are held accountable. Data collection and disclosure (Chapter 9) is critical to strengthening the transparency of water use and accountability of water users. Finally, global governance arrangements (Chapter 10) must be designed in a

Box 4.2. The common good framework

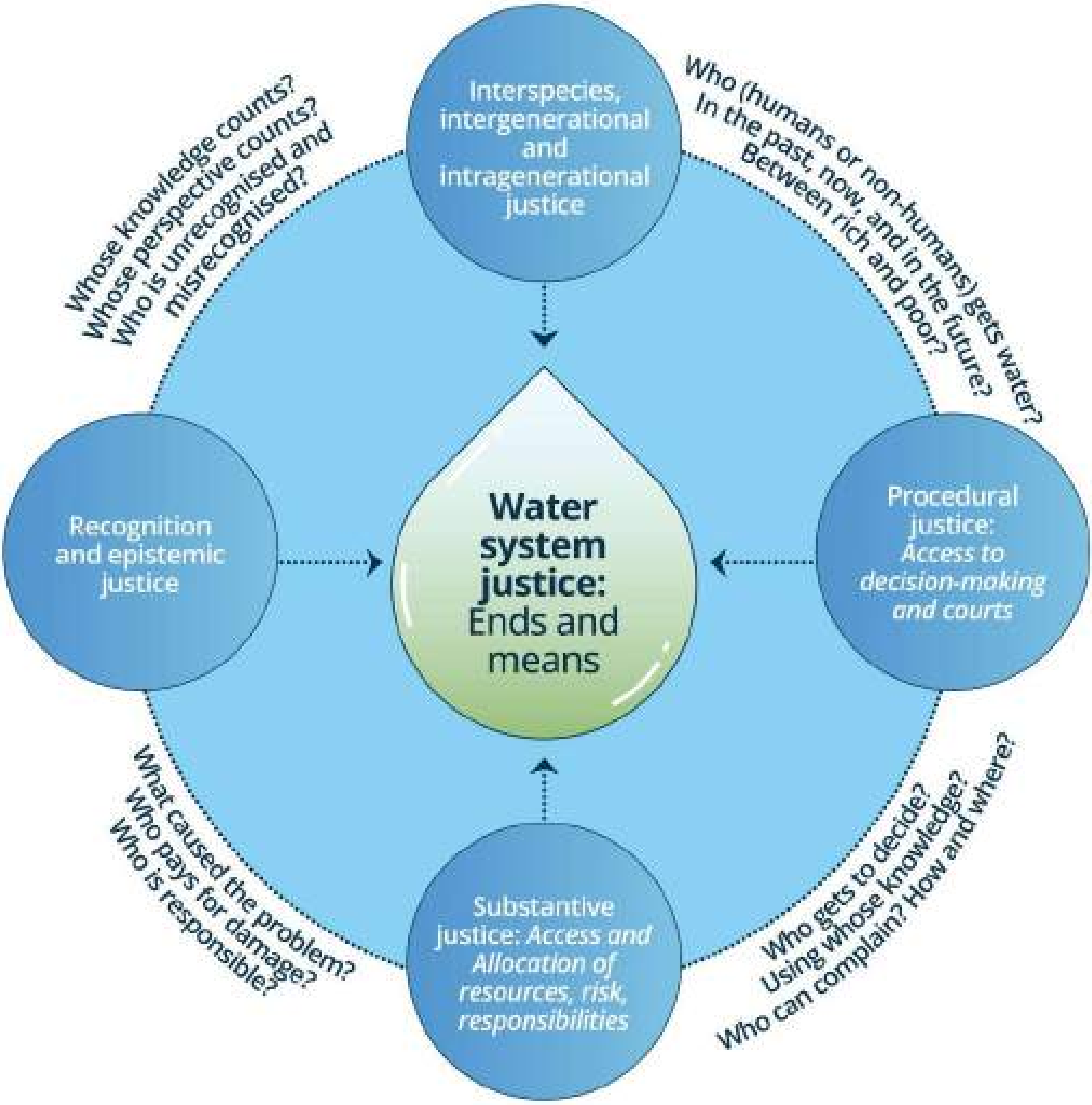
In Mazzucato (2024) the following 5 principles are used to underpin the common good framework.

- ***Purpose and Directionality*** *emphasises that growth must have a clear direction with policy tools and public institutions designed in an outcomes-oriented way to tackle shared missions.*
- ***Co-creation and Participation*** *ensure different stakeholders are involved in decision-making and implementation processes.*
- ***Collective Learning and Knowledge-Sharing*** *are essential for the systemic and collective action required to tackle the global water crisis.*
- ***Access for All and Equitable Sharing*** *of resources, risks, and rewards, and related responsibilities are also crucial.*
- ***Transparency and accountability*** *are essential for accessible and visible governance, with a focus on the governance of water data and utilities.*

way that is truly collective and participatory so that one part of the world is not adversely affected by actions in another part of the world.

The five common good principles help guarantee that justice and equity are baked into the global response to the water crisis. The common good framework is used in Mazzucato and Zaqout (2024) to consider the implications for designing solutions to our biggest water challenges. A robust definition of Water System Justice is required. The GCEW endorses a definition of justice beyond equity and redistribution, and the Earth Commission provides a valuable reference, explored below.

Figure 4.2: Building off the Earth System Justice Framework (Gupta et al., 2023)



Defining Water System Justice

Justice in the water space has mainly been framed at the local, basin, or national level, focused on ensuring that people's basic needs, sources, and supplies are not polluted, that uses are prioritised, and to a lesser extent, that decision-making processes are inclusive (Bosch et al., 2024, and Sultana, 2018). Water justice goes beyond equity to address a broader analysis. The rights of rivers and Indigenous rights are increasingly promoted. In transboundary basins, the priority is typically sharing water equitably, balancing the needs of different riparian states, and reducing harm to others; international law calls for equitable and optimal use of the watercourses.

Like conventional water economics, and resource and irrigation management, water justice debates focus on blue water, with little attention to green water except in the context of land- and water-grabbing.

Building on the Earth Commission's Earth system justice framework (Gupta et al., 2023), analysis for this report explores what it means to restore the hydrological cycle and manage water sustainably for people today, for future generations, and for all living beings. The result is a framework for Water System Justice (Figure 4.2) that aims to tackle structural injustices from a pragmatic approach and identify a just and sustainable path for blue and green water management (Gupta et al., 2023).

A distinctive feature of Water System Justice is to assess ends and means simultaneously. Water System Justice starts with the hydrological cycle as a global common good. It includes justice elements (recognition, epistemic; interspecies, intergenerational, and intragenerational; procedural; and substantive) and applies them to water to operationalise just ends and just means. Water System Justice argues that conservative justice is unable and unlikely to address the justice issues of the Anthropocene:

- **Recognition justice**, acknowledging all the rights-holders and stakeholders in each context, their different situations, their knowledge, values, identity and culture, as well as past and present injustices that might affect them. It counters exclusion and prioritises people and communities who are poor, marginalised, or have disabilities.
- **Epistemic justice**, or how knowledge is generated, shared and valued, addressing possible biases, power imbalances and inequities in representation and access to information (Fricker, 2007; Byskov & Hyams, 2022). It means recognising, incorporating and sharing diverse sources of knowledge about water, including scholars from the Global South, Indigenous groups and peoples with different knowledge about water, and those writing in languages other than English.
- **Relational justice**, emphasising that justice is about our relationships with the Earth and fellow living beings (interspecies), with future generations (intergenerational), and with one another (intragenerational).
- **Procedural justice** or giving all actors relevant information and the possibility to influence decisions. If unhappy, they should be allowed to protest and go to court. Positive action is often needed to help the most marginalised to participate effectively.
- **Substantive justice**, which supplements procedural justice – and its focus on governance – by considering the outcomes. If procedural justice merely implements existing policies and laws, it can exacerbate substantive injustice. Substantive justice defines a just allocation of water and of water-related risks and opportunities.

These elements should be implemented simultaneously to operationalise just ends and just means. Ends are operationalised through: (1) boundaries and standards for water quantity and quality; and (2) minimum access. Means are operationalised by addressing: (1) the drivers of water crisis and inequality; and (2) the distribution of harm/risks, resources, and related responsibilities.

AAchieving Water System Justice requires a programmatic approach that combines local realities with global necessities. By recognising and valuing diverse knowledge systems, ensuring inclusive and intersectional governance, and addressing procedural and substantive justice, we can move towards a more equitable and sustainable water future. For example, one way of ensuring Water System Justice is by ensuring that all children before the age of five do not die from a water-related cause (see mission 5). Each chapter in Part 2 of the report will investigate the changes required for the relevant policy area to ensure that water justice is integrated from the start.

Estimating water requirements for a dignified life

One key implication of putting justice at the centre of our response to the global water crisis is rethinking what it means to live with enough water for a dignified life – not just to survive, but to thrive. This is an objective, an outcome that requires policymakers to redesign the tools and institutions at their disposal to deliver on it. One of these tools is the way we measure how much water humans need to lead a dignified life. It is 14 years since access to safe drinking water and sanitation was recognised as a human right (UN, 2010). Fifty litres of freshwater per person per day (l/p/d) represents a minimum human right to water for basic health and sanitation (WHO, 2003). While progress is slow, the human right to water and sanitation has been a cornerstone of the global water agenda.

Revising these assessments requires an economy-wide approach, taking water use from all sectors into account, and a systemic approach, considering both blue and green water flows. Factoring in food and industry for adequate human development, as well as blue and green water supplies, presents a far higher integrated estimate of freshwater needs for a dignified life. This is a bottom-up estimate of human freshwater requirements, not a definition of the freshwater planetary boundary. Falkenmark & Rockström (2004) lay out the foundational logic for human water requirements based on diet, domestic, and industry needs, arriving at an estimated 1,500 m³/p/year (y). This estimate remains largely intact twenty years later, though we have revised the diet estimate based on nutritional requirements and updated industrial usage based on current rates.

While the total estimate can be refined, local solutions will not suffice to secure such volumes for large populations in most parts of the world. Trade has a role to play but is affected by misaligned policies and by the water crisis, as discussed in Chapter 3. The global community needs to explore and realise the conditions for trade (food trade most prominently) to contribute to efficiency (delivering food, valuing water endowments, and sound water policies), equity (just allocation and cost-efficiency), and environmental sustainability (protecting water and related ecosystems that support a stable hydrological cycle).

In estimating human water requirements, it is important to distinguish water *withdrawal* from water *use*. Water withdrawal is the direct, human extraction of blue water for societal application in irrigated agriculture, industry, and municipal contexts (distributed as piped water for human uses). A proportion of withdrawn water is consumed – water use – while the rest is returned to the environment. Consumptive water use refers to water withdrawn from a source and made unsuitable for reuse in the same basin (Gleick, 2000), such as green water flow from vegetation, including crops.

The policy focus for estimates of the human need for freshwater – which impacts its priority in economics and governance (e.g., SDG 6) – is on the minimum human right to domestic water (for drinking, cleaning, and health). This amounts to 50-100 l/p/d, or an annual human water requirement of 18-36 m³/p/y.

In this report, we widen the human requirement for freshwater, as a necessary basic accounting factor in the economy, to include the freshwater required for food and industry. While including water for domestic, food, and industry uses is a significant broadening, it still underestimates human freshwater needs, as it excludes freshwater for sustainable ecological functions and services, like moisture feedback (generating future rainfall), carbon sequestration in plants and soil, and nurturing biodiversity in stable ecosystems.

For food we estimate the freshwater requirements per person based on dietary requirements in calories (kcal) and average water productivity estimates for animal-based kcal versus plant-based kcal. We utilise a range of daily caloric (kcal) estimations:

- Food and Agriculture Organization (FAO) estimated average adequate diet of 2,700 kcal/p/d based on empirical average food balance between supply and demand at country level.

- EAT-Lancet Commission Planetary Health Diet (PHD) estimates for an optimal diet for human health and environmental sustainability (2,500 kcal) of which 14% is animal-based and 86% plant-based.

- The Earth Commission's (EarthC) contribution, with two levels of just access to a minimally sufficient diet: the upper level using the EAT-Lancet PHD (2,500 kcal) and the lower level using the WHO guideline for emergency nutrition needs (2,100 kcal) (Rammelt et al., 2022).

Despite wide variability in water productivity (m^3/ton or kcal) for different crops, agricultural yield levels, and hydroclimatic zones around the world, the evidence shows a relatively similar range across hydroclimatic zones for different stable food crops (the basis for food groups in diets) at approximately 1,000 m^3/ton (with a range of 500-5,000 m^3/ton explained by yield levels determined by management practices rather than hydro-climatically, which in turn result from the linear relationship between yield and transpiration).

Evidence indicates that animal-based kcals consume an order of five times more freshwater (per unit kcal) on average compared to plant-based kcals (FAO). As a generic guide for human water requirements (recognising large local variability due to different crops, hydroclimates, management, and diets), this translates to ≈ 0.5 m^3/1,000 kcal of plant-based foods and ≈ 4 m^3/1,000 kcal of animal-based foods.

Combining these gives the following estimates of human freshwater requirements for food for different dietary targets:

Table 4.1: Estimates of human freshwater requirements

Daily total target kcal estimate	Animal-based kcal (14% of total)	Plant-based kcal (86% of total)	l/p/d (avg water productivity)	m^3/p/y
2 700 (FAO)	400	2 300	~ 4 300	~ 1 570
2 500 (PHD)	340	2 160	~ 3 860	~ 1 410
2 500 (EarthC max)	340	2 160	~ 3 860	~ 1 410
2 100 (EarthC min)	285	1 815	~ 3 240	~ 1 180

This provides us with a global average water requirement for food of approximately 3,800 l/p/d (with a range around 3,200-4,300 l/p/d).

Industrial demands are difficult to define at a per capita level, given the uneven global distribution of water-consuming industries. At the same time, one can argue that in a globalised world with significant virtual trading of goods, dividing the global estimate of industrial freshwater consumption by the global population provides an indicator of the level of freshwater consumption per person to keep the world of today operating.

Global industrial water withdrawal in 2020 was approximately 920 km^3 (Richie, H. & Roser, M. (2024). Distributing this evenly across the 2020 global population of 7.9 billion people yields a nominal 322 l/p/d or 118 m^3/p/y. Despite the difficulty in explicitly allocating this at a per-capita level locally, we do think it is valuable to include it in defining human water needs.

The total updated human water requirement for a dignified life thus amounts to approximately 4,000 l/p/d (3,800 + 50 + 322 for food, domestic and industry, respectively).

In addition to this, approximately one third of mean annual blue water flow should be set aside for environmental water flows in aquatic ecosystems. The green water equivalent – the minimum level of soil and plant moisture in any given landscape/watershed – is unknown.

Conclusion

To shape markets that balance competing priorities of efficiency, equity and justice, and environmental sustainability in a way that provides enough water for citizens to lead a dignified life, we need a new direction, guided by clear and ambitious missions. By making investments and crafting policies that strategically promote efficient, equitable, and sustainable solutions, governments can catalyse economy-wide transformations that lead to necessary water outcomes. Setting ambitious targets to achieve them in an outcomes-oriented way can provide the foundation for such just transformations.

Chapter 3 sets out the priority to consider a range of policy packages, because no single policy can achieve the competing requirements of efficiency, equity, and environmental sustainability. Part 2 will set out five critical water missions before examining the policy changes we need in innovation, partnerships, financing, utilities, data, and global governance.

5. Innovations to tackle water's critical mission areas

Key takeaways

This chapter outlines the main innovations central to the ambition of securing a future of sustainable and equitable access to water everywhere, using a mission-centred approach to radically transform how water is used, supplied, and conserved.

We must centre national and global efforts on five critical water mission areas to achieve this transformation:

1. **Launch a new revolution in food systems** to improve water productivity in agriculture while meeting the nutritional needs of a growing world population.

2. **Conserve and restore natural habitats** critical to protect green water.

3. **Establish a circular water economy**, including changes in industrial processes, so that every drop of used water generates a new drop through reuse.

4. **Enable a clean-energy and AI-rich era with much lower water intensity**.

5. **Ensure that no child dies from unsafe water by 2030**, by securing the reliable supply of potable water and sanitation for underserved communities.

These missions address the most significant and interconnected challenges of the global water crisis. The first two seek a transformation in agriculture and natural habitats, to conserve water and enhance yields, redress the neglect of green water, and stabilise the hydrological cycle.

Recognising the surge of urbanisation globally, the next two missions focus on promoting circular economy solutions and reducing the water intensity of rapidly growing industries like clean energy and AI. Finally, we must ensure affordable access to clean water and sanitation for every vulnerable community.

These missions must drive policy shifts, innovation, and the alignment of the public and private sectors and communities. We must value water properly to reflect its scarcity and its critical role in sustaining the natural ecosystems that people and planet depend on. We must cease the under-pricing of water across the economy, and re-channel the subsidies that support its unsustainable usage toward promoting water-saving solutions and providing targeted support for the poor and vulnerable.

These innovations are within our reach. Many water innovations had not reached economic viability in the past, but we are now at an inflexion point. Mature and proven technologies, many less capital-intensive than before, can be scaled up more easily than even a decade ago. Others involving experimental solutions show significant promise and need support.

However, we need new ways of governing to unleash a wave of innovation and investment. Policymaking must become more collaborative, accountable, and inclusive of all voices, especially those of youth, women, marginalised communities, and the Indigenous Peoples who are on the frontlines of water conservation.

Innovation is central to the ambition of securing a future of sustainable and equitable access to water everywhere. Innovations to achieve this future are intrinsically tied to water justice. Today's use of water in many sectors is excessive and wasteful, and skewed towards large, industrial consumers and the better-off. Solutions to manage water demand are therefore critical to ensure access for those who lack it. They must also cater to the unique needs and constraints of small-scale farmers and the informal sector and correct for insecure land and water rights.

Equally, we need proper pricing of water to discourage profligate use, and subsidies to support the poor. The widespread under-pricing of water can also skew the location of the most water-intensive crops, and water-guzzling industries, such as data centres and coal-fired power plants, to areas most at risk of water stress.

Critically, we must innovate simultaneously for water, biodiversity, and climate. Water innovation is the low-hanging fruit in efforts to tackle climate change, but there is a risk of water and climate solutions working at odds. Our missions must aim to both conserve blue and green water and reduce greenhouse gas (GHG) emissions.

This chapter outlines the key innovations needed in policies, institutions and technologies to radically transform how water is used, supplied, and conserved. They should be driven by a mission-centred approach, as set out in Chapter 4.

We must centre our ambition on tackling five critical water mission areas:

1. **Launch a new revolution in food systems** to improve water productivity in agriculture while meeting the nutritional needs of a growing world population.

2. **Conserve and restore natural habitats** critical to protect green water.

3. **Establish a circular water economy**, including changes in industrial processes, so that every drop of used water generates a new drop through reuse.

4. **Enable a clean-energy world and an artificial intelligence (AI)-rich era** to be achieved with much lower water-intensity.

5. **Ensure that no child dies from unsafe water by 2030**, by securing the reliable and affordable supply of potable water and sanitation to every underserved community.

These five missions address the most significant and interconnected challenges of the global water crisis as highlighted in Chapters 2 and 3. The first two seek a transformation in agriculture and natural habitats, to conserve water and enhance yields, redress the neglect of green water, and stabilise the hydrological cycle. Recognising the surge of urbanisation globally, the next two missions focus on promoting circular economy solutions and reducing the water intensity of rapidly growing industries like clean energy and AI. Finally, we must ensure affordable access to clean water and sanitation for all.

Each of these missions require a significant scaling up of innovation and investment. They can be unlocked through the policy and governance shifts elaborated on in this chapter. Underpinning these moves, the way we do government must be different. Policymaking must become more collaborative, accountable, and inclusive of all voices, especially those of youth, women, marginalised communities, and the Indigenous Peoples who are on the frontlines of water

conservation. Governments must also establish more symbiotic partnerships to tackle major water challenges, as examined in Chapter 6. It also requires a systematic effort to collect and make available data that can steer investment towards sustainable and just practices, and help communities contribute to the development of locally relevant solutions. Finally, this approach requires new forms of financing – especially patient investment with a long-term direction – which in-turn require greater certainty in policies and regulation.

Mission 1: Launch a new revolution in food systems

Agriculture is key to addressing the intertwined challenges of water, climate, and food security (Khokhar, 2017). Transforming food systems is especially necessary as food demand is projected to rise 60% between 2019 and 2050, driven by growth in the world population, urbanisation, and incomes (Falcon, Naylor, & Shankar, 2022).

Food systems are under threat from climate change; the depletion of groundwater, surface water, and green water (the moisture stored in the soil and plant life); water pollution; and inequitable distribution systems. These threats affect all regions, from Sub-Saharan Africa, where climate change is projected to impact agricultural yields (Munang, et al., 2014), to Asia, where water-intensive rice cultivation faces critically low levels of groundwater or surface water (Benavides, et al., 2023) (Tan, et al., 2014) (Wu, Wang, & Avishek, 2021); to Latin America, Africa and the EU, where droughts are causing severe losses in farm outputs (Burford, et al., 2022) (Benavides, et al., 2023); to the US Colorado River Basin, where unsustainable extraction has been outstripping future water supply (Heggie, 2020).

The Green Revolution more than a half century ago lifted agricultural yields for wheat and rice significantly, helping to avert famines and lift incomes of rural populations dramatically in some parts of the world. However, its reliance on large quantities of water, pesticides, and nitrogen-based fertilisers cannot remain viable without fundamental changes in techniques. We can no longer assume the natural stability of blue and green water flows,[15] given the increasing variability in hydroclimatic conditions. Further, food systems are responsible for more than one-third of global anthropogenic greenhouse gas emissions: nitrous oxide (most of which is generated by agricultural practices) accounts for over 6% of total greenhouse gas emissions (The Business Times, 2024) (FAO, 2021). Runoff from excessive or inappropriate use of fertilisers and pesticides affects aquatic life, with nitrogen and phosphorus contributing to coastal "dead zones", such as those appearing in the Gulf of Mexico (Howard, 2019).

We set out three goals below and how we can achieve them through a new revolution in food systems. They can transform agriculture into being both a beneficiary and custodian of natural ecosystems.

Goal 1: Improve water productivity by reducing water usage in agriculture by a third, while increasing crop yields

Agriculture accounts for 70% of freshwater withdrawals globally. Studies find that agriculture has also been responsible for about 70% of deforestation in tropical and subtropical regions (United Nations Office for Disaster Risk Reduction).

15 Blue water flows in streams and rivers, and is held in lakes, reservoirs and as groundwater in water tables and aquifers. Green water is the water stored as soil moisture and in vegetation, which returns to the air through evaporation and transpiration.

We must couple innovations for water productivity with policy measures to reduce overconsumption of water in agriculture, so as to maximise yield per drop of water, preserve soil moisture and meet growing food demands while stabilising the hydrological cycle and ensuring adequate supply of water for all.

Current irrigation systems in much of Asia rely on approaches that have existed for centuries. New irrigation technologies and other solutions can be scaled up to produce more crop per drop with the same or lower levels of water use. A major shift is required in rice cultivation, which has relied heavily on continuous flooding for irrigation. Techniques such as alternate wetting and drying, direct seeding, and rice/shrimp rotation applied in several Asian contexts (Bangladesh, Pakistan, Philippines, and southern Vietnam) have reduced water usage by 10-20% (Lampayan, Rejesus , Singleton , & Bouman, 2015) (Appendix 5.1 Box 1).

Micro-irrigation[16] technologies have been found to improve water efficiency while increasing yield and crop quality. They have short payback periods of six months to two years. Soil moisture sensors and satellite technologies have also advanced and seen cost reductions, enabling farmers to optimise irrigation systems and build resilience to weather extremes (Appendix 5.1 Box 2).

There is also significant scope to expand use of fertigation for both water and fertiliser efficiency. Drip fertigation has been able to raise water use efficiency by 25%, while increasing crop yields and significantly reducing nitrogen and phosphorus concentrations in surface runoff (Li, et al., 2021) (Song, et al., 2023).

The use of rainwater harvesting systems should be enhanced to bolster the resilience of rain-fed agriculture, which accounts for 80% of the total cropland and more than half of the world's food production (FAO, 2020). Almost 20% of global cropland is suitable for rainwater harvesting and conservation strategies, especially in large parts of East Africa and Southeast Asia. Examples of ground-up practices include *zaï* pits in Burkina Faso, where organic materials are placed in small soil pits in fields, enabling additional water storage of up to 500% of the soil capacity and improving soil fertility (CGIAR) (Appendix 5.1 Box 3). National governments play a critical role in ensuring that an enabling environment exists to support, promote, and regulate the role of the private sector in incremental improvements of rainfed agriculture.

Further, we should scale up examples where the use of climate-resilient seed variants, diversification of crops, and sustainable cultivation techniques (such as composting and mulching) have enabled consistent yields with resilience against weather extremities. The contexts for the successful examples in Appendix 5.1 Box 4 should be studied further to see if they can be replicated. For instance, life-science research enabled the development of resilient rice varieties that are drought- and flood-tolerant, resistant to disease, and can be cultivated with a threefold reduction of water (Luo & Yin, 2013).[17]

A combination of these interventions could improve irrigation efficiency and potentially yield substantial reductions in agricultural water use. While water irrigation will inevitably have to grow in the next few decades to meet growing food needs, simulations by the International Food Policy Research Institute found that three interventions taken together – increasing drip- and precision-irrigated areas, and accelerating take-up of seed variants – can generate 26% savings in irrigated water usage by 2050.[18] With more aspirational targets,[19] adoption of these interventions could reduce water usage by up to 50%.

However, measures to enhance water-use efficiency are unlikely to reduce agricultural water use if the savings are channelled into expanding irrigated areas, increasing cropping intensities, or a switch to more water-intensive crops. These measures for irrigation efficiency should be supported by water accounting and regulatory frameworks at field and basin levels to cap or reduce total water withdrawals.

16 Micro-irrigation consists of drip irrigation systems, subsurface drip irrigation systems, and micro-spray irrigation systems.

17 For instance, rice strain T5105, known as Temasek Rice, piloted in Banda Aceh and Yogyakarta, has a reported yield twice as high as standard with a slightly longer growth duration, without compromising grain quality (Marker-assisted breeding of Thai fragrance rice for semi-dwarf phenotype, submergence tolerance and disease resistance to rice blast, 2013). In addition, aerobic rice varieties are being developed to have drought tolerance and high yielding ability. The expected yield can be up to triple that obtained under upland conditions (Chapter Four - Aerobic Rice Systems, 2011).

18 This scenario assumes a moderate but achievable adoption level of 25%, phased in gradually from 2025 to 2050.

19 This scenario assumes a more aggressive adoption level of 50%.

Goal 2: Accelerate the shift to regenerative agriculture systems from 15% of global cropland to 50% by 2050

We must sustain soil health to improve water infiltration and storage, which are crucial to food production and the resilience of crops to droughts. Regenerative agriculture aims to achieve this through the following approaches (Appendix 5.1 Box 5):

- Improving soil water retention, including cover-cropping, intercropping, mulching, and agroforestry practices.
- Storing organic carbon in the soil to enhance soil water-holding capacity.
- Maintaining and restoring natural and semi-natural habitats in agriculture and forestry landscapes.

These approaches are relatively low-tech and versatile solutions for most geographies and crop types. They also improve the livelihoods of smallholder farmers through lower input costs (notably water, fertilisers, pesticides), reduced labour, and increased crop yields. Farmers' annual incomes in southern Ethiopia have increased with regenerative agriculture practices (Gebeyehu, 2023). Studies on intercropping soybean with wheat found that farmers can significantly improve profitability, with a return on investment of 15-25% over ten years (Bugas, et al., 2023).

As of 2019, only 15% of global cropland had adopted such systems (Kassam, Friedrich, & Derpsch, 2022). We must aim to adopt regenerative agriculture systems for at least 50% of global cropland by 2050, which is shown to be achievable in regions such as South America (Kassam A. , Friedrich, Derpsch, & Kienzle, 2015).[20] To get there, we should leverage large agroindustry coalitions to transform entire supply chains, including creating demand for regenerative agricultural products from farmers, off-takers, and traders. (Appendix 5.1 Box 6). We should also restore sustainable traditional farming techniques and take action to protect the resource rights of vulnerable groups.

Goal 3: Aim to achieve a 30% share of plant-based proteins by 2050, especially in higher-income countries with high red meat and dairy consumption

Critically, we must reduce our collective dependence on water-intensive foods. Our aim should be to gradually increase the share of plant-based proteins to about 30% of proteins in people's diets by 2050.[21] This is especially needed in high-income countries that have high red meat and dairy consumption, but cannot be applied indiscriminately to many lower-income countries, where consumption of animal-sourced food remains important for under-nourished populations, particularly young children and pregnant women.

This global shift is ambitious, and consumer habits will take time to evolve. However, they are necessary because animal-based foods are major drivers of the agriculture sector's impact on water use, greenhouse gas emissions, and natural habitat loss.[22]

Examples show how we can make a graduated shift to plant-based and other alternative proteins[23] through research and development (R&D) and culinary innovations. Recent studies suggest that change is feasible with low-lift interventions (Sousa, 2024). For example, making plant-based dishes the main option in hospitals and on campuses, with meat only available upon request, and giving these dishes more appealing names has proven effective

20 The Agribusiness Task Force (part of the Sustainable Markets Initiative) has highlighted the need to increase regenerative agriculture to make up 40% of global cropland by 2030, up from 15% today (Sustainable Markets Initiative, 2022).

21 Plant-based proteins in this report refer to foods produced from plants that can substitute directly from conventional animal-based products, such as meat, seafood, milk, eggs and dairy. The share of alternative proteins in global protein consumption, with plant-based proteins forming the much larger portion (relative to microorganism and animal-cell-based proteins) is projected to grow from 2% in 2020 to 11% by 2035. This has been estimated to rise to 16% by 2035 if there are technological step changes, and to 22% if supportive regulations and shifts in taxes and subsidies encourage a progressive shift away from conventional animal-based foods. (Witte, et al., 2021). There are encouraging signs. For example, fermentation-based proteins have achieved significant growth in funding over the last year, from public, philanthropic and commercial sources. Greater investments in experiments in the alternative protein sector will help bring it closer to achieving broad consumer appeal and commercial viability.

22 Animal-based foods are estimated to account for 57% of agricultural greenhouse gases, with beef and cow milk making up 34%. Further, about 30% of water in agriculture is directly or indirectly used for livestock production (Gerbens-Leenes, Mekonnen, & Hoekstra, 2013).

23 There are multiple environmental benefits to consuming plant-based proteins. A gram of pulse protein utilises 90% less water on average than a gram of beef protein and 50% less than pork protein (Makonnen, et al., 2010). Plant-based protein requires less fertiliser use, leading to about 90% less aquatic nutrient pollution than conventional meat (Respect, 2023). Growing legumes, which are primary in plant-based proteins, improves soil biodiversity as well as water- and nutrient-use efficiencies in crop production (Santo, et al., 2020).

(Sousa, 2024).[24] Such subtle nudges towards plant-based food can change food habits without removing a sense of individual choice.

There is also ample scope to revitalise traditional staples that are less water-intensive, and high in protein and other nutritional content, such as varieties of millets that India is seeking to promote (India Brand Equity Foundation, 2023) (Thapak, et al.).

Plant-based and alternative proteins must be price-competitive to increase demand. Today, the cost of alternative proteins is about twice that of conventional animal proteins (Good Food Institute, 2022). Costs can be lowered by increasing the protein content of these crops, such as through breeding approaches (Good Food Institute, 2022).[25] The cost of microorganism-based alternatives can also be decreased by increasing the efficiency of conversion into protein and the use of lower-cost feedstocks such as fermentation byproducts (Good Food Institute, 2022).

Policy and institutional shifts for revolutionising food systems

The adoption of improved technologies by farmers, especially small-scale-producers, is often hampered by a range of barriers and constraints. These include financial barriers, such as affordability and limited access to loans; institutional barriers, such as insecure land tenure rights; the risks inherent in adopting new practices and technologies; and the lack of sufficient incentives to cut down on water use.

Several policy and regulatory shifts can help address these barriers. Sustainable agriculture can be strengthened in some contexts by addressing insecure land and water rights, enabling farmers to invest in measures to increase soil health and water storage. For instance, land in Africa is typically held by either the community chief or the government (MacFarquhar, 2010). In many places, farmers cannot obtain loans without providing their land titles as collateral, and hence have limited access to machinery and fertilisers (Mambondiyani, 2016).

Efforts are needed especially to empower women, who make up over 40% of the world's agricultural labour force. They still often face significant discrimination when it comes to land and livestock ownership, participation in decision-making and access to credit and financial services (FAO, 2011).

The bulk of today's huge agricultural subsidies have been assessed to be price-distorting and environmentally harmful.[26] Incentives must be provided to farmers through well-designed pricing and subsidy schemes to encourage efficient water use whilst ensuring that farmers' livelihoods are not threatened. Inefficient and harmful subsidies should be redirected to improve water management in agriculture and support regenerative agriculture:

- In Gujarat, India, a pilot programme that paid farmers for pumping less groundwater had significant impact (Hagerty, et al., 2024). In several states in India, efficient delivery of subsidies for micro-irrigation technologies has been proven effective in encouraging their adoption (Appendix 5.1 Box 7; Chapter 3).
- Pajaro (California), United States (US), is a case study of how pricing irrigation water helps preserve groundwater resources and fund measures to recycle the region's groundwater.[27] Indirect pricing mechanisms should also be explored.
- Kilimo, an Argentinian company, incentivises farmers by providing them with a revenue stream from water savings, connecting them with corporates looking to invest in water security in the same catchment area (Global Water Intelligence, 2024).

24 University of California San Diego Health has been replacing some meat in hospital cafeterias with plant-based dishes such as mushroom stroganoff, resulting in a 13% reduction in red meat purchases since 2017 (Sousa, 2024).

25 For example, Benson Hill, an agriculture biotechnology company, embarked on a yellow pea breeding and commercialisation programme to increase yellow pea's protein content, improve its taste, and improve the crop for easier and more sustainable processing (2021).

26 This refers only to agricultural subsidies (excluding subsidies in the broader water sector). The FAO/UNDP/UNEP estimated in 2021 that USD 470 (87%) of the estimated total USD 540 billion are price-distorting and environmentally and socially harmful (UNEP, UNDP, FAO, 2021). The WTO estimated that total support for agriculture in 84 countries is USD 635 billion per year, and may be even more if including all countries, and when updated. If we apply the same 87% ratio for harmful subsidies as in the FAO UNDP/UNEP report, it will be USD 553 billion (Thibert, et al., 2019).

27 Research on the programme revealed that a 20% increase in the price of groundwater resulted in a 20% decrease in the extraction of groundwater (Davenport, 2023).

To encourage these measures, trade negotiations that deal with domestic agricultural support could be reformed, such as by improving the transparency of subsidies to enable better assessment of the environmental externalities and encouraging their repurposing towards more equitable and environmentally sustainable outcomes.

Regenerative agriculture is likely more profitable in the long run due to crop and profit diversification and reduced agricultural input. Still, farmers could experience profit losses during the transition period (Petry, et al., 2023). Innovative support measures are needed to de-risk and support this transition, such as cross-value-chain collaboration to ensure demand for regeneratively produced crops, cost-share programmes, crop insurance schemes, and government subsidies (Majolein Brasz, 2023).

We can also scale up lessons from co-operative or cluster farming, which allows smallholders to pool their resources, employ irrigation technologies or regenerative agriculture practices at a low cost, increase their bargaining power with suppliers and buyers, and access government support and financing more easily.[28] Ethiopia is turning towards cluster farming as a pathway to improve water efficiency, increase yields, and reduce poverty in a sector dominated by subsistence and smallholder farmers (Dureti , Tabe-Ojong, & Owusu-Sekyere, 2023). Farm households receive proportionate benefits based on their land contributions to the cluster, and commit to cultivating crops prioritised by the cluster in adherence to farm-agronomic recommendations (Dureti , Tabe-Ojong, & Owusu-Sekyere, 2023). Similarly, Water User Associations bring together farmers, government officials, and marketers to manage a shared irrigation system, allowing farmers to play a more active role in sustainable water resource management (Chai, et al., 2014). Appendix 5.1 Box 8 offers further examples in China, Ethiopia, the Philippines, Tanzania, Uganda, and Vietnam.

Measures to enable more water-efficient technologies should be coupled with regulation and enforcement against excessive water use. Farms might otherwise expand the areas irrigated, or switch to more water-intensive, higher-value crops.[29] China has moved towards active groundwater management and removal of subsidies for water and water-intensive crops (Rin). We should also take a basin-wide water-management approach to mitigate the impact of reduced flows on downstream users while promoting irrigation efficiency improvements upstream (Ingrao, Strippoli, Lagioia, & Huisingh, 2023). It is important to recognise that, while individual farmers have an incentive to expand irrigated areas with the water saved, markets would correct for an excessive supply of crops in the long-term. Where there is unmet demand for crops, it also remains advantageous that they be produced on farms with the most water-efficient techniques.

Beyond irrigation, green water must be systematically assessed in economic and policy analysis. This includes recognising the economic value of green water, such as the benefits that forests and inland water ecosystems bring to rainfed agriculture through precipitation and soil moisture-retention, and how the depletion of green water contributes to droughts.

Coordinated experimentation with field-based technologies and policy interventions is needed across diverse contexts so that best practices can be made evident and scaled up. Complementing this, we must collect high-integrity water data and track water footprints across the entire supply chain to spur investments and the widespread application of water-saving innovations (Chapter 9).

Transparent regulatory frameworks and greater government involvement in the form of open research, tax credits, and subsidies are needed to unlock investments in plant-based and alternative proteins (Good Food Institute, 2022). Regulations and norms should recognise the continued role that meat-based proteins play in meeting nutritional needs, especially in lower-income countries. Clear technical thresholds should be set for alternative protein companies to gain regulatory approval; regular reviews of the evolving science are also needed. Providing pre-submission compliance advice helps companies navigate what might be complex regulatory processes and enables faster entry to market (EIT Food, 2023).

28 Cluster farming retains individual farm ownership and autonomy over decision-making in response to market incentives. It is distinct from collective farming, which involves a communal approach to ownership and decision making, and has had less success.

29 A study in Andhra Pradesh found that subsidies for drip-irrigation systems resulted in shifts in cropping patterns to more remunerative and irrigation-reliant crops, which increased revenues. However, there was no reduction in groundwater pumping, as farmers transferred excess water to adjacent plots (Fishman, et al., 2021).

Finally, greater policy coherence and water accounting across sectors and policy domains is crucial for agricultural transformation. Concerted engagement of all stakeholders – in particular small-scale farmers and women – can bring multiple sources of knowledge, values, and information to the table, building trust and thus allowing more effective implementation of the shifts we describe (FAO, 2020) (OECD, 2018).

Mission 2. Conserve and restore natural habitats critical to protect green water

Since 1970, land-use change has had the largest relative negative impact on terrestrial and freshwater ecosystems. Infrastructure development, urbanisation, and agriculture account for more than 70% of deforestation pressures (EIT Food, 2023), with agricultural expansion the largest contributor (CBD Secretariat, 2020) (FAO, 2021b). These incursions into forested lands and other natural habitats have reduced green water flows and downwind precipitation, lowering agricultural yields and threatening food security, particularly in regions dependent on rainfed agriculture.

Crucially, the world must implement the goals for protecting and restoring natural ecosystems adopted in the Global Biodiversity Framework (GBF). Priority should be given to protecting and restoring areas that can generate the greatest water-security benefits. Efforts must also be made to recognise the rights of Indigenous Peoples, who are stewards of one quarter of the planet's land, accounting for about 40% of the remaining natural lands worldwide (Fernández-Llamazares et al., 2024; Garnett et al., 2018).

Goal 1: Restore at least 30% of degraded forest and inland water ecosystems globally by 2030, aligned with GBF Target 2

Achieving the GBF target of 30% restoration of degraded forest and inland water ecosystems will restore their functional capacity, promoting the return of green water stocks and flows through precipitation and soil moisture-retention (The World Bank, 2023). According to the Intergovernmental Platform on Biodiversity and Ecosystem Services, the benefits of restoring degraded land are on average ten times higher than the costs of inaction of continuing degradation, estimated across nine different biomes (Intergovernmental Platform on Biodiversity and Ecosystem Services, 2018). The cost of restoring the damaged Waza floodplains in Cameroon was estimated to have been recovered in less than five years, and to have brought about USD 2.3 million additional income per year (Russi, et al., 2013).

Restoration of degraded ecosystems need not be expensive, as it can be achieved through simple innovations. The regreening of Uganda's Cattle Corridor is an example. A shift to corralling cattle at night to concentrate manure catalysed a reversal in land degradation (Appendix 5.1 Box 9).

Goal 2: Conserve 30% of forest ecosystems globally by 2030, aligned with GBF Target 3

The GBF target of protecting 30% of terrestrial lands by 2030 will not bring more lands under conservation if the target is reached only in regions where forested ecosystems are intact. However, most water-scarce basins and a significant share of evaporation sheds contributing to green water transfers are in ecoregions where nature is already degraded (Chapter 3). While only 8% of the most forested ecoregions are extensively protected (50%

coverage), there is potential for over an additional 40% to reach the same degree of protection (Dinerstein, et al., 2017). The 30% target should be pursued as a benchmark for nations to support the functioning of ecosystems within their jurisdiction, considering each country's circumstances, priorities and capabilities, and respecting the rights of Indigenous Peoples and local communities, including over their traditional territories.

Goal 3: Conserve 30% of inland water ecosystems by 2030, aligned with GBF Target 3

Inland water ecosystems such as lakes, rivers, swamps, peatlands, and wetlands act as a source and purifier of water, providing resilience against flood and droughts, supporting biodiversity, and providing water for agriculture and other uses, including carbon storage and sequestration. Yet they remain under threat, with natural wetlands declining by 35% between 1970 and 2015 – three times the rate of forest loss (Convention on Wetlands, 2021). Wetlands, particularly peatlands, are critical for green water conservation and provide blue water services. They help reduce flood and drought risk with up to 90% water-holding capacity (The Ramsar Convention on Wetlands, 2021).

Policy and institutional shifts to ensure green water conservation and restoration

The importance of blue and green water in a stable hydrological cycle must be recognised as prerequisite for the restoration and conservation of natural habitats, and the overall biodiversity and climate agenda. Achieving the shared vision of living in harmony with nature hinges on a stable hydrological cycle. If blue and green water remain threatened, the aims of the Global Biodiversity Framework to protect and restore biodiversity will be undermined.

It is critical that the role of green water be recognised in decision-making processes for policies, strategies, and investment:

- Nature and climate financing involving nature-based solutions should measure and account for protecting and restoring blue and green water, specifically that of forests. This includes exploring how the value of green water can be recognised and incorporated in Payment for Ecosystem Services (PES) schemes.

- Regulations for water management should also encompass blue and green water. Most environmental laws and regulations focus on safeguarding the quality and quantity of blue water, neglecting the role of green water, in part due to a lack of universal metrics for green water.

- Decision-makers should incorporate green water into cost-benefit evaluations, strategic environmental assessments, land use planning, and environmental-impact assessments, among other policy processes. Green water must be recognised in National Biodiversity Strategies and Action Plans (NBSAPs) of the Convention on Biological Diversity parties, to inform priorities and financing streams.

Making use of different qualitative and quantitative approaches[30] to reflect the multiple values will inform the implementation of policies to manage conservation and restoration (Russi, et al., 2013). For example, the Mhlathuze municipality in South Africa undertook a strategic catchment assessment to estimate in monetary terms the value its ecosystem provides, such that certain zones of and around the biodiversity hotspot were identified to be conserved while other zones were developed (Russi, et al., 2013).

30 Qualitative analysis (e.g., through participatory methods) describes the benefits and value provided by these ecosystem services that are not easily quantified (e.g., impact on security, well-being, cultural value), while quantitative data represents the state of and changes in the ecosystem services provided (e.g., groundwater availability in cubic metres, number of people who benefit from access to clean water from wetlands).

Data to ensure informed decision-making is foundational for any institutional shift. We must develop a methodology to track how changes in the landscape affect blue and green water stocks and flows and vice versa and build data to determine baselines and track progress. The Global Commission on the Economics of Water advocates for the establishment of a global water data infrastructure (Chapter 9).

This mission requires particular emphasis on international partnerships:

- The Congo Basin Forest Partnership seeks to protect the world's largest carbon sink and vital source of rainfall through sustainable forest management and easing pressures on forests. Critically, the Partnership highlights the need to conserve in a way that allows for economic development (Nkuintchua , et al., 2024). Studies estimate that every USD 1 invested in restoring degraded forests can yield between USD 7 and USD 30 in economic benefits (Ding, et al., 2017).

- Similarly, the Freshwater Challenge (FWC) launched at the United Nations (UN) 2023 Water Conference, a country-led initiative, aims to accelerate the restoration of 300,000 km of degraded rivers and 350 million hectares of degraded wetlands by 2030, as well as conserve intact freshwater ecosystems.

Mission 3: Establish a circular water economy

There is significant untapped potential for wastewater reuse of around 320 billion cubic metres per year (UNEP, 2023), equivalent to about 8% of total freshwater withdrawals — close to the total amount withdrawn for municipal water.[31]

There are also massive inefficiencies in water distribution. In total, some 40% of municipal urban water supply is wasted through leakage, such as from ageing pipelines[32] (Jamieson, et al., 2024). Minimising these leaks will generate public savings: non-revenue water costs USD 39 billion per year globally, which could be used to improve water infrastructure. Furthermore, about 11.9 billion kg of CO_2 emissions are generated each year in treating water lost before it reaches the customer (S&P Global Ratings, 2023).

Most fundamentally, we must reimagine the linear model of water management, in which water is extracted, used, and released back into the environment. We can create a circular water economy that allows the world to capture the full value of water by retaining and reusing every drop, as well as recovering the value of all byproducts. A water recycling rate of 50% means that one drop of used water could produce another drop. But only 11% of estimated total domestic and industrial wastewater produced is reused. In addition, we should explore recovery of minerals and by-products in wastewater, which can generate revenue streams. Many components of wastewater can be recovered for beneficial purposes: water for agriculture and industry, nutrients for agriculture (nitrogen, phosphorous), and energy (methane) (US Department of Energy).

Goal 1: Cut leakages and non-revenue water in half by 2030

A circular water economy starts with retaining water within the system and preventing loss. We must accelerate innovations to reduce non-revenue water in municipal systems by at least 50% by 2030. These include using pipes that are less leak-prone (e.g., moving from traditional cast iron to ductile iron), and employing sensor technologies for early leak detection, automated pressure control in water pipes for pumped water networks, and efficient pipe repair (Appendix 5.1 Box 10).

A satellite-based and AI-enabled leak-detection system has been validated and expanded following a successful pilot funded by the Inter-American Development Bank across Argentina, Brazil, Mexico, Trinidad & Tobago, and Uruguay. A project in Buenos Aires, covering 5,000 km of pipes, reported a 128% increase in leak detection efficiency, and water savings of 2 million m^3 per year (sufficient for 16,700 persons) (2022) (ASTERRA, 2023).

Reducing non-revenue water does requires hardware and a shift in the way utilities are

31 Globally, 10% of freshwater withdrawals is estimated to be used for municipal purposes.

32 On average, non-revenue water accounts for approximately 40% of the water supply, reaching as high as 80%. In Asia, non-revenue water averages 35% in cities. In Europe, it averages 26% (AVR) (Jamieson, et al., 2024).

managed. Manila Water reduced non-revenue water in the East Zone of Metro Manila from 63% in 1997 to 13% in 2023 by strengthening community partnerships and involvement in reporting leaks and illegal connections, besides deploying technical and engineering solutions (Manila Water, 2023). To ensure sufficient attention is provided to each district, the service provision territory was restructured and decentralised with focused business plans for each district (Aqua Tech , 2023) (Appendix 5.1 Box 11).

Goal 2: Recycle 50% of water to enable every drop of used water to generate a new drop

We must drive water reuse in the municipal and industrial sectors so that, in total, every drop of used water contributes to a new drop of water.[33] While treatment for recycled water is more costly than for raw water, the prospective costs will be magnitudes smaller than the economic, health, and human toll of the day when water runs dry.

Advances in membrane and solvent-based technologies increase access to affordable water recycling (Singapore Institute of Technology , 2023). They enable efficiencies and reduce operational expenses, while increasing the yield of recovered resources (Singapore Institute of Technology , 2023). The application of specific water recycling methods (e.g., membrane-based and electro-deionisation technologies) nevertheless depends on scale and context, with industrial water in particular varying in quality requirements.

Reusing treated municipal wastewater for drinking water is becoming more common. This is usually done indirectly by adding the treated water to reservoirs or ground water[34] (e.g., Singapore's NEWater or Orange County Water District's Groundwater Replenishment System). Direct reuse, where treated wastewater is used for drinking water, is also being adopted in Namibia, the Philippines, and the US (Appendix 5.1 Box 12).

On-site water reuse is also an important alternative in urban settings. These decentralised systems reduce the risk of underutilised assets, such as in peri-urban areas of low-income countries where there is uncertainty in expected urban growth. Beyond ensuring public health, decentralised systems coupled with off-grid renewable energy sources offer the opportunity for affordable and sustainable water reuse. An added benefit is greater control over design, installation, and maintenance afforded to end-users, fostering a sense of local ownership (Appendix 5.1 Box 13).

There is substantial scope for reuse of water in industrial facilities. Wastewater from one industrial process can often be reused with minimal or no treatment in another. Optimisation at plant level allows for significant reductions in water footprints of industrial users and ensures long-term operational sustainability, particularly for water-intensive industries. Leading semiconductor wafer fabrication plants in Chinese Taipei operate at above 80% recycling rates, including through the direct reuse of reject streams from ultra-pure water production for process cooling. In food production, PepsiCo found that more than 50% of the water used during the potato-chip cooking process could be recovered and treated to safe drinking standards, saving approximately 60 million litres of water per year (PepsiCo, 2022) (Appendix 5.1 Box 14).

Reuse of wastewater (treated and non-treated) for irrigation is becoming more prevalent, particularly in arid and semi-arid countries like Australia, Egypt, and Israel. Egypt has been reusing nutrient-rich agricultural drainage water to sustain agricultural activities (IHE Delft Water and Development Partnership Programme, 2022).

Goal 3: Create new value by recovering other resources from wastewater treatment

Beyond reusing every drop in the water system, resources such as nutrients, energy, heavy metals, and minerals can be recovered during wastewater treatment:

33 To illustrate, recycling 50% of the water supply once will result in every drop of used water producing 0.5 drops of usable water. This 0.5 drop of "new" usable water will then produce another 0.25 drops, then 0.125 drop and so on. Theoretically, one drop of used water will produce another drop of water (i.e., 0.5 + 0.25 +0.125 + 0.0625 +...= 1), which is a multiplier of 2. If this used water, such as greywater — wastewater (excluding toilets) generated in households or office buildings — can be recycled and used one more time onsite before being discharged to the sewer and recycled once more, the multiplier effect will be enhanced further. For example, with 50% of greywater being recycled on-site and 50% of the final used water in the sewer recycled to be reused, the multiplier will be 3.

34 Indirect portable reuse introduces purified water into an environmental buffer (e.g., a groundwater aquifer or a surface water reservoir, lake, or river) before the blended water is treated at a water treatment plant and piped to the consumer.

- **Energy recovery**. Wastewater volumes contain significant embedded energy[35] that can be used to meet electricity demand (Manzoor Qadir, 2020). Integrating used water treatment and solid waste processes can harness synergies through the water-energy-waste nexus. Singapore's Tuas Nexus project will be powered in part by biogas produced by the co-digestion of used water sludge and food waste (National Environment Agency (Singapore)).

- **Nitrogen, phosphorous, and potassium recovery**. Assuming full nutrient recovery from wastewater, we can meet 14.4% of global nitrogen demand as a fertiliser nutrient and 6.8% of phosphorous and 18.6% of potassium demand (Manzoor Qadir, 2020). The Durham Advanced Wastewater Treatment Facility in the US state of Oregon, which serves 500,000 customers, produces up to 40 tonnes of fertiliser every month using the nitrogen and phosphorous recovered (Ostara).

- **Heavy metals recovery**. Effluent from mining and electroplating is typically rich in precious metals like copper and chromium. These can be recovered through technologies such as ion-exchange processes or absorbent materials (Waterman Engineers Australia).

- **Biosolids as fertiliser**. Brazil-based Companhia de Saneamento Ambiental do Distrito Federal (CAESB) used biosolids extracted from wastewater to fertilise corn. The experiment led to higher-than-average grain yields, with biosolids 21% more efficient than mineral fertilisers (The World Bank, 2020).

- **Biosolids as non-conventional construction material**. By transforming sludge into a safe and stable product for construction through gasification and sintering (solidifying material through heat and pressure), the problem of waste sludge disposal as a public and environmental health problem can be alleviated. Maynilad Water Services in Metro Manila, the Philippines, plans to produce bio-bricks from its water reclamation plant to be used for constructing non-load-bearing structures (Talavera, 2024).

Policy and institutional shifts to promote a circular water economy

Achieving a circular water economy will require well-designed public-private partnerships (PPP) and regulations to ensure better delivery efficiency, non-revenue-water reduction, and extensive industrial wastewater recycling.

An ecosystem to support startups and growth enterprises, which are often at the forefront of these innovations, is critical to prevent them from being priced out of PPP opportunities. Governments can refine procurement policies to incentivise participation, such as by requiring local partnerships or the involvement of small and medium-sized enterprises' participation in certain contracts. In the private sector, specialised water funds provide capital and advisory support for water and wastewater treatment startups. These can help companies participate in water plant projects, manage risks, and structure operational agreements (Water and Wastewater Asia, 2017).

Technical regulations and standards for wastewater resource recovery must be enhanced and enforced to ensure public safety, and set a common benchmark for investors to reference, and for utilities to work towards (OECD, 2020). There are few policy or regulatory frameworks that provide incentive to stakeholders to seek resource recovery from wastewater treatment. Regulations governing water utilities, public health, and environmental services must be coherent and differentiated so that they are fit for purpose. Most regulations and standards for wastewater focus on treatment and disposal into the environment, not on resource recovery and reuse (The World Bank, 2019).

Mission 4: Enable a clean-energy and AI-rich era with much lower water-intensity

As the world transitions to clean energy and harnesses the benefits of AI, the water resources crucial to this shift are often overlooked. It is paramount to address this intersection and

35 This energy can be recovered through: (a) thermal energy from wastewater and its treatment; and (b) chemical energy in the form of biogas generated from anaerobic digestion of wastewater sludge.

implement strategies that advance a sustainable path towards a low-carbon and AI-enhanced future. Without compromising water availability and quality, we must radically improve water efficiency and pollution management in three areas: (1) clean-energy generation; (2) semiconductor manufacturing and data centres; and (3) mining of essential materials.

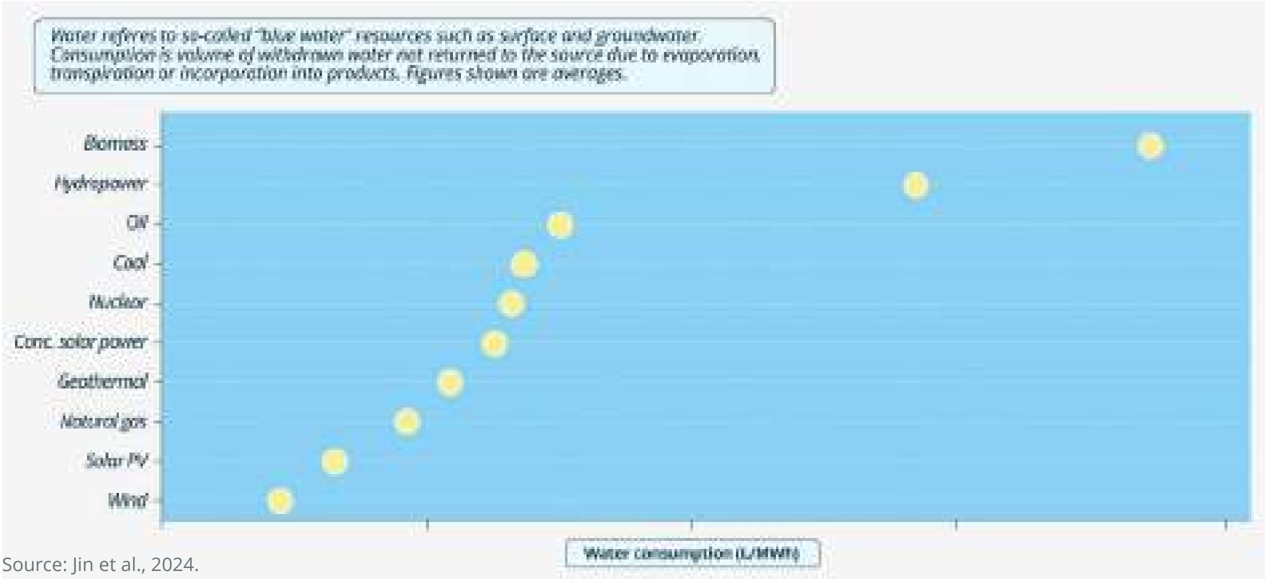
Goal 1: Generate clean energy with low water-intensity

The path to lower emissions could exacerbate or be constrained by water stress unless we reduce water use in renewable energy sources across the entire life cycle, from production to operation. The mix of new energy solutions is therefore critical, encompassing:

- **Low water-intensity**[36] wind and solar photovoltaics, mainly requiring water in the upstream production of wind turbine and electrical components.
- **Moderate water-intensity** thermal-power-based sources, including fossil fuels (oil, coal, natural gas) and renewable sources (nuclear, geothermal).
- **High water-intensity** biofuels, which have significant surface and ground water needs for irrigation.

Technologies for a water-efficient, clean-energy transition have been developed and must be scaled up. Nuclear and geothermal plants must be designed with water-efficient cooling towers and use seawater or recycled water. Biofuels should be sustainably produced based on best practices outlined in our call to revolutionise agricultural systems, above, and not involve land-use changes. (Importantly, we need to expand the production of second-generation biofuels, which turn waste biomass into resources without additional water needs and reduce carbon emissions from burning crop residues.) Solar panels require frequent water cleaning to maintain optimum performance,[37] an unsustainable practice in desert areas where solar farms are prevalent. A new, waterless cleaning method developed by MIT engineers leverages electrostatic repulsion to remove dust from solar panels, without the need for water (MIT News Office, 2022). Finally, green hydrogen remains an important development priority for the long term. With cumulative water consumption of 20-30 litres per kg of hydrogen, it is significantly more water-efficient than blue hydrogen, which consumes 32-39 litres per kg, considering the water consumed through natural-gas production and the eventual carbon capture and storage required (Ramirez, et al., 2023).

FIGURE 5.1: Water consumption by electricity generation technologies



Source: Jin et al., 2024.

36 Water-use intensity refers to blue water withdrawn and not returned to the source due to evaporation, transpiration, or incorporation into products, per unit of energy generated.

37 Accumulation of dust on solar panels can reduce energy output by as much as 30% in just one month. Brushing the dust off the panels is not preferred given the likelihood of irreversible damage due to abrasion.

Goal 2: Improve water efficiency in industry, from cooling data centres to mining essential minerals

Solutions are imperative to ensure that rapidly growing digitalisation and the proliferation of AI do not consume an inordinate share of water (Appendix 5.1 Box 15). More water-efficient methods of producing semiconductor chips must be embraced, such as using sprays instead of baths to rinse wafers and remove impurities without sacrificing cleanliness, and reusing water used to cool down equipment. Efforts are also being made to replace wet processes with dry ones where possible (e.g., anisotropic etching with dry plasma etches instead of wet isotropic etches) (PUB, Singapore's National Water Agency, 2022) .

Demand for data centres in the AI era will come with both increased energy needs and water use for cooling and humidification. Proper upstream design and planning are necessary to improve water efficiency and prevent harmful extraction from watersheds. Google's data centre in Hamina, Finland, uses its proximity to the sea to utilise seawater for cooling (Metz, 2009). Data-centre provider Equinix aims to increase cooling-water efficiency by controlling the pH level and using mechanical filtration to remove solids and limit turbidity (Meta, 2016). Innovative operational solutions that reduce water use must also be considered, such as computational load shifting among Google's data centres to optimise cooling loads (Metz, 2009) and Meta's optimisation of relative humidity, temperature, and airflow in its data centres (Zhou, et al., 2024).

Changes are also needed in how the world mines and produces minerals such as lithium, nickel, and copper, which are foundational to both clean energy and AI – from solar panels, electric vehicles, and battery storage to electricity networks and semiconductor chips – to address their environmental consequences, as well as social impacts in each context. They currently have high water-use requirements and often pose contamination risks with long-lasting pollution effects (Gupta et al., 2024).[38]

Moreover, up to a quarter of the world's critical minerals are mined in arid areas or those facing high levels of water stress (Lakshman, 2024). Mining can improve its water footprint by adopting dry processing technologies and replacing evaporative cooling with less water-intensive methods. Closed-loop systems can be adopted to recycle tailings water and reuse lower-quality water from dewatering mines. To reduce pollutant discharge, mining facilities must manage runoff, and cover waste rock and ore piles. They must also employ wastewater treatment systems to remove contaminants, such as by membrane filtration and using coagulants to precipitate metals.

Policy and institutional shifts to enable a clean-energy and AI-rich era with lower water-intensity

Robust, properly designed and implemented water policies can go a long way in ensuring water-wise energy transition and AI diffusion. They include water abstraction and pollution charges designed to signal the opportunity cost of using water and the cost of pollution.

Regulations should require large water-users to conduct water audits and develop conservation plans to identify and implement water-reuse measures, mandating minimum water recycling standards for industrial processes and adoption of water-efficient equipment.

Sectoral benchmarking is useful to identify best practices and encourage take-up by laggards. The Mining Association of Canada's Water Stewardship Protocol and Framework is one such example (Mining Association of Canada). Their protocol comprises four performance indicators: (1) water governance, (2) operational water management, (3) watershed-scale planning, and (4) water reporting and performance indicators. It also requires facilities to engage with water users and communities-of-interest in the watershed, to participate in watershed-scale planning and governance fora, and to disclose performance against water objectives (The Mining Association of Canada).

38 For instance, nickel production is projected to grow significantly by the adoption of a hydrometallurgy process called high-pressure acid leaching to produce battery-grade nickel from limonite ores (S&P Global, 2024). This process has more than double the water intensity of conventional pyrometallurgy, which is better suited for sulphide ores (International Energy Agency, 2022). On the other hand, lithium production involves high eco-toxicity risks, mostly due to its leaching process. The shift from traditional brine-based production to rock-based lithium production also leads to an almost tenfold increase in eco-toxicity values (Songyan, et al., 2020).

Positive spillovers for local communities should be a priority as new industrial projects are implemented, while ensuring that local access to water resources is not restricted or degraded. As green hydrogen projects expand, policymakers should also ensure that desalination plants do not degrade surrounding marine ecosystems. Hydropower plants should be right-sited and managed within and across boundaries to minimise disruptions to downstream riparian communities.

Environmental safeguards on activities should be in place along the entire production chain – from preventing mine acid drainage, to treating pollutants associated with green hydrogen production.

Mission 5: Ensure that no child dies from unsafe water by 2030

Over 2 billion people do not have access to safely managed water. Over 1,000 children under five die every day from illnesses caused by unsafe water, and poor sanitation and hygiene (United Nations Children's Fund (UNICEF), 2023). Water utilities have made significant progress in reaching poor and vulnerable communities in many cities (e.g., Phnom Penh in Cambodia, Porto Alegre in Brazil, and various cities in China).

We can and must bring water to every vulnerable community and child in every region. The solutions must address the more efficient and equitable distribution and use of water. They should include wider adoption of decentralised water treatment solutions that are now viable and affordable. Critically, we must ensure resilience of the water supply, including restoring and expanding wetlands and other natural storage solutions, and investing in new, energy-efficient desalination solutions.

Goal 1: Build decentralised water treatment systems

CCentralised water infrastructure brings economies of scale and remains fundamental. However, it requires large capital expenditure and its extension to remote communities is often not financially viable. Technological improvements allow us to ensure access to clean and safe water for all communities by complementing centralised utilities with decentralised water treatment systems.

Water treatment technologies and processes have been developed to make this possible and can be scaled up. They include affordable yet durable membranes created by strengthening polypropylene with carbon nanoparticles. Smart approaches using sensors can be employed to provide early detection of potential membrane damage, allowing operators to monitor and adjust systems remotely (Woo, et al., 2022). With increasing demand and the challenges of implementing traditional, centralised water treatment plants, low-cost point-of-use (POU) systems offer a scalable solution in low and middle-income countries and are seeing uptake even in high-income countries. The use of membrane-based filtration, sometimes coupled with chemical treatment processes in decentralised water systems, has been shown to deliver safe water for consumptive and domestic uses in Myanmar and Tanzania. New membranes using carbon nanoparticles are also being applied in Vietnam, with the ability to treat high turbidity water without chemical pre-treatment, with vastly less sludge and at lower cost compared to conventional systems (Appendix 5.1 Box 16).

To complement decentralised water treatment systems and ensure access to safe water, passive and point-of-use chlorination of water can be adopted to provide biologically safe water. Passive chlorination can support water systems with intermittent flow, while point-of-use chlorination can disinfect water collected from informal sources. Point-of-use chlorination has potential for scalability in low-income countries, especially when paired with innovative distribution methods such as vouchers for monthly doses of dilute chlorine solution or incorporating water treatment tools into safe birthing kits (Dupas P. H., 2016) (Appendix 5.1 Box 17).

Goal 2: Close the global water storage gap, especially through rainwater harvesting and wetlands

Storage is critical to resilient and equitable water access in the face of droughts and floods.[39] However, water storage in wetlands has declined

39 The global water storage gap is the difference between the amount of water storage needed and the amount of operational storage (natural and built) that exists for a given time and place. This gap is growing and is expected to widen further with rising water demand and greater incidence of floods and droughts.

40% and in groundwater up to 70% from 1971 to 2020 (McCartney, et al.). Built water storage has also declined as sediments fill man-made reservoirs, coupled with poor maintenance of structures such as dams and water tanks (Pengestu, 2023). Expanding water storage will require both natural and built systems, and can be a combination of the two, as in managed aquifer recharge (MAR).

Water harvesting is critical for mitigating droughts and dry spells and builds resilience for rainfed agriculture. About 70-80% of rainfall is typically accessible to plants as soil moisture. However, this can decrease to as little as 40-50% on inadequately managed land (Rockström), which calls for the mainstreaming of rainwater management strategies to improve yields and water productivity.

Natural storage can provide effective flood mitigation by absorbing and slowing the flow of water, while enhancing dry-season access to water through slower release, such as from mountain glaciers and snowpacks. Depending on absorptive capacity, large wetlands act as sponges, absorbing wet season flows and releasing the water over the dry season (The World Bank, 2023).

With increasing incidences of floods encroaching into residential areas, countries and municipalities are working to mitigate floods and restore natural storage. In Chad's Doukour Valley, the Adoulous Group, a women's co-operative, installed a water-spreading weir in a runoff bed. This weir retains water during the high-water period, functions as a dam, and recharges the groundwater table for several months, helping 17 villages in the semi-arid Sahel region irrigate their crops (The World Bank, 2024). The Netherlands' Room for the River programme restores natural floodplains by giving rivers more room to flood safely (Dutch Water Sector, 2019). This shift from traditional, vertical flood defences to the horizontal widening of rivers increases their capacity across a wider area (Goossen, 2018).

Managed aquifer recharge is a promising adaptation that uses built structures to reverse groundwater decline.[40] Aquifers can also be artificially recharged with wastewater to exploit nature's ability to treat wastewater. In Spain, a consortium of farmers uses seasonal excess surface water collected in basins, canals, and pits to infiltrate water to the Los Arenales aquifer. This active management of the aquifer reversed decline in groundwater levels despite lower average precipitation. If managed aquifer recharge was not implemented, farmers would have spent 16% more economic resources to pump the same water volume. Farmers were also able to sustainably maintain irrigation, with an approximately 19% increase to irrigated areas, without detriment to groundwater levels (Goossen, 2018).

Goal 3: Prevent water contamination at the source

Water quality around the globe is under severe threat from pollutants and contaminants, undermining ecosystem services, development, and human health. The dire situation is epitomised by eutrophication, characterised by excessive algae growth due to an overabundance of nutrients, ultimately leading to dead zones when the algae die and decompose.

While physical treatment infrastructure and regulatory standards are foundational, more innovations are required to address water contamination at its source:

- **Constructed wetlands filter agriculture runoff**. A 12-year study in Illinois, US, found that these nature-based solutions are cost-efficient and effective at reducing nutrients in runoff that would otherwise affect local waterways. A relatively small wetland, around 6% of the agricultural area, can reduce nitrogen runoff by 50% (The Nature Conservancy, 2024).

- **Enforcement of industrial waste discharge** can be improved with integrated environmental sensors powered by AI data analysis. Chinese Taipei's Environmental Protection Administration has used such a system since 2019, leading to the detection of 48 incidents of illegal discharge and fines totalling over NTD 36 million (Ministry of Enviroment, 2023).

- **Decentralised sanitation solutions** can prevent the discharge of untreated sewage.

40 Managed aquifer recharge can be done with excess monsoonal runoff to mitigate downstream flooding and can enhance the quality and quantity of groundwater storage. Interventions ranging from field bunds and rock weirs in drainage channels, to floodwater diversion can help to reduce runoff and concentrate water to be stored in deeper aquifers.

France's SPANC (public service for off-grid sanitation) regulates the design and implementation of off-grid solutions by homeowners and monitors their proper operation and maintenance. Fees for regular inspection are billed to the owner, along with optional maintenance services provided by SPANC (Public Service France, 2022).

Goal 4: Develop and scale up energy-efficient desalination techniques

Affordable and energy-efficient desalination is part of the mix of solutions to achieve long-term water resilience. The innovations being explored include improved integration of renewable energy, better control of membrane fouling, and technologies that can work on the seabed, which reduce the impact of desalination on the marine environment and are less energy intensive.

Small-scale desalination solutions that tap renewable energy sources are growing, providing more affordable access to water in remote, arid places. While the unit-cost of production of water is more expensive than large-scale desalination plants, the savings from eliminating transmission networks means that such systems could be as cost-effective as conventional municipal-scale systems.[41] Low-energy desalination solutions that do not require membranes are also being piloted by engineers at MIT and in China.[42] The system is able to produce 4-6 litres of drinkable water per hour, and its extended lifespan and independence from electricity have enabled cheaper clean water production than that of producing tap water in the US (Chu, 2023) (Appendix 5.1 Box 18).

Improved membrane materials, such as graphene with openings the size of a single atom, aim to reduce the energy-intensity of desalination and bring affordable water filtration to countries that cannot afford large-scale desalination plants (The University of Manchester). Brine produced as part of the desalination process also provides opportunity for resource recovery, being rich in calcium and magnesium salt (Parada, et al., 2023). This provides sustainable extraction compared to land-based mining and can increase the commercial viability of desalination facilities. Modularised subsea desalination systems are currently being trialled (Flocean). Freshwater can be produced with up to 50% reduction in desalination energy consumptions by leveraging the natural pressure of deep-sea water. Further, the lower organic content of deep-sea water (with minimal algae and bacteria due to the lack of sunlight) reduces the pre-treatment requirements as compared to a land-based facility.

Policy and institutional shifts to ensure access to clean water

Utilities and governments must employ an efficient and equitable demand-management model that provides users with the water supply they require, discourages overuse of water, and ensures that the poor are subsidised. A multi-pronged strategy involving utilities and regulators is necessary.

Price and subsidy policies should incentivise conservation and ensure access to water resources for the poor and vulnerable. Regularly adjusted tariffs are necessary to provide water utilities with revenue for routine operations, maintenance, and investment in new infrastructure. They also provide the resources to extend the reach of water infrastructure which, coupled with targeted support for the poor and underserved, is critical to ensuring inclusivity. Various tariff structures and subsidies can achieve this (Leflaive, et al., 2020):

- In Chile, an increasing block tariff coupled with coupons for low-income households helps the poor pay their water bills (Leflaive, et al., 2020). The increasing block tariff has a base price for a certain level of water consumption with additional tariffs on higher consumption 'blocks'. This encourages lower water usage and ensures a stream of revenue to support the utility's operating costs and investments.

- Singapore has adopted a block tariff system for households, coupled with targeted subsidies for lower- and middle-income households. The large, first tariff block includes a water conservation tax, and enables the recovery of the long-term cost

41 Elemental Water Maker's small-scale solar-powered desalination solution is fully automated and can be remotely monitored. It can achieve 70% energy savings with a further lowering of the energy input by reusing residual energy from brine (Elemental Water Makers).

42 This low-cost system has seawater circulating in swirling eddies, like oceanic thermohaline circulation, and is placed in a structure that absorbs the sun's heat effectively (Ralls, 2023). This heat causes water in the circulating eddies to evaporate, leaving the salt behind. The water vapour is then condensed into pure drinking water while the residual salt is expelled.

of producing and distributing water. While 96% of households fall into this first block, a significant proportion of them receive a targeted and progressive rebate to ensure affordability.

- A study in Kenya showed that a uniform price (such as at the marginal cost of service delivery) alongside a targeted rebate subsidy based on the amount of revenue in excess of costs yields optimal social, economic, and financial outcomes (Fuente, Kabubo-Mariara, Kimuyu, Mwaura, & Whittington, 2019).

Governments can also implement differentiated regulatory regimes to achieve last-mile water supply and sanitation service delivery. In 2017, the Colombian national government introduced differential schemes to incentivise utilities to close persistent gaps in service provision for the poor, initially setting lower regulatory standards with the expectation that these will progressively rise over time. This approach yielded positive results in Medellin, where services were extended to nearly 15,000 previously unserved households (Polaníai, 2022) (Polanía, 2021) (Appendix 5.1 Box 19).

On the demand side, measuring consumption accurately by mandating the installation of water meters encourages users to be more conscious of their consumption. The advent of smart water meters – which provide more granular and real-time insights on water use – opens a new frontier for demand management and data-driven behavioural nudging practices (e.g., goal setting, comparative data, gamification, and loss-aversion messaging).

Many contexts offer greater opportunities to tackle local water and health challenges together. By working collaboratively rather than in silos, we can unlock more impactful solutions for safe water, sanitation, hygiene, and health, such as by incorporating water treatment (including chlorine-based products) into health packages. We should strengthen such innovative partnerships at every level.

Meanwhile, national public finance coupled with central government funding must support decentralised systems. While central governments should facilitate technical assistance to local governments, direct channelling of funds to district authorities can significantly enlarge their water and sanitation capabilities. Another mechanism is earmarked grants that ensure there are sufficient funds for water and sanitation. Upon implementation, decentralised solutions can be kept affordable through collection of user fees. User fees for cost recovery allows these systems to remain financially sustainable (Appendix 5.1 Box 20). For example, Portugal has a model in which municipalities are both shareholders and clients of multi-municipal water utility companies, alongside the central government holding the majority

equity stake (Oliveria, 2023). This model strikes a balance between maintaining municipal jurisdiction over water systems and aggregating multiple municipal utilities unto larger operational units to enable quicker infrastructure development, better management, improvements in technical capacity, and better absorption of EU funds (Zenha, et al., 2017).

Ultimately, management of blue and green water storage, especially wetlands, must be a multilateral priority. It requires good data on water storage, to be shared across countries who share the same precipitationshed (Chapter 9). Remote sensing plays a key role in providing geospatial information required to monitor changes in water storage. Measuring surface-water elevation using earth observation technology can provide estimates of changes in total water storage.

Solving water: An unprecedented opportunity

A future of sustainable, affordable and equitable
A future of sustainable, affordable, and equitable access to clean water everywhere is fully within reach. Water innovations have had uneven success in achieving economic viability in the past, especially without a supportive policy environment. However, we are at an inflexion point. Mature and proven technologies, many less capital-intensive than before, can be scaled up more easily than even a decade ago. Others involving experimental solutions show significant promise and need support.

The fundamental opportunity lies in reorienting policies and institutions, through active consultation with all stakeholders, to spur a wave of innovation and investment centred on the five missions set out in this chapter. Priority must be given to discouraging land-use changes that negatively impact blue and green water. Crucially, water must be priced properly, accompanied with targeted financial support to enable access by every vulnerable community, so as to discourage excessive consumption and supporting demand for water-saving innovations in every sector of the economy.

6. Partnerships, property rights and contracts for more water justice

Key takeaways

Partnerships between government and business should be more symbiotic. Short-termism and financialisaton plague some water and non-water markets, leading to the inequitable allocation of water between users. A new approach to partnerships, especially between the public and private sectors, must be based on a new approach to risk: where risks are shared between actors, the rewards should be shared as well.

Governments can embed conditionality in (new or renewed) water permits, contracts, and property rights – while addressing the challenge of dealing with permanent property rights and permits that cover twenty years or more and affect adaptive governance – to enable equitable and affordable access, and deliver a more water-secure world. Conditionalities can be used to, among other things: improve water conservation, the efficiency of water use, and how much water should be returned to ecosystems and the hydrological cycle and in what quality; direct investment for water-intensive agriculture and industries towards regions that are less water stressed; reinvest profits in productive business activities, such as R&D and innovation around water; or reinvest profits into watershed and water-basin conservation programs so the source is governed sustainably.

Water is being overallocated and misallocated, which means it must be re-allocated. In most countries and regions, the Earth system boundary for surface water has been breached, while minimum needs (water, food, energy) have not yet been met. To get back within safe and just water boundaries, the challenge is to reduce or make more efficient net water consumption and reallocate water more equitably between uses and users, from those who use too much to those who do not have enough. Rethinking the terms and conditions of partnerships is a key leverage point.

A common good framing pays attention to the 'how' as much as the 'what', especially to how different actors in the system partner and collaborate to achieve shared missions. Innovating to achieve the five mission areas is a collective process and requires the right kinds of partnerships. Mobilising the finance to drive the mission areas also requires the right kinds of partnerships. This chapter investigates how to design partnerships between government, business, utilities, and other economic actors to deliver on the five mission areas.

Every day, thousands of new partnerships and projects are designed worldwide that directly or indirectly require water. Food, energy, industry and mining need large volumes of water. Many contracts that define the terms of the partnerships do not mention water or take for granted that they will receive the water necessary for conducting these projects.

National and international projects involving large sums of money are concretised in and protected by contracts between different actors (private-private, public-private, public-public, investor-state). Importantly, states have sovereignty over the blue water that flows through their borders, the land from which green water evaporates, and the green water that falls within their territory. This means that governments can play a vital role in re-allocating water between actors in the public interest.

However, two legal issues constrain states' ability to control, allocate, and reallocate water. First, companies have protection against state interference through bilateral, multilateral, and plurilateral investment treaties that protect foreign investors. Second, water rights were historically accessed through land ownership, purchase, and water rights granted by the state.

Despite these challenges, there are ways to re-allocate water from those who use too much to those who need it. To do so, governments need to change how they shape markets and how they partner with other economic actors. There must be a redefinition of the relationship and partnership between government, business, utilities, labour organisations, Indigenous groups, and other rights-holders and stakeholders in water-related issues. There must be a shift from partnerships that lead to inequitable, inefficient, and unsustainable water use to symbiotic partnerships that have equity, efficiency, and environmental sustainability baked in from the start.

Designing these partnerships to become more symbiotic is of particular importance today because the struggle to govern water in the public interest is intensifying, with increasing water demand and decreasing availability exacerbated by trends such as climate change, demographic shifts, and increasing and changing patterns of consumption (Boretti & Rosa, 2019; UN Water, 2021). Already, water-use boundaries have been crossed at local to global levels, indicating that water resources have been over-allocated.

To get back within safe and just water boundaries, the challenge is not only to reduce or make more-efficient water consumption, but also to reallocate water more equitably between users, from those who use too much to those who do not have enough.

This chapter examines what it means to design more symbiotic water partnerships based on a new set of principles. It also makes the case for governments to shape water permits, contracts, and property rights, so that we transform sectors and industries to align with water missions and other public policy objectives.

Problems with water partnerships today

Many water partnerships set a course towards a water-scarce future rather than delivering public value by contributing to the sustainable and just use of water.

Broadly, there are five ways that states allocate water:

1. **Existing water use:** Many countries recognise historical water use, which continues under new and/or postcolonial legislation (Bosch et al., 2021). However, many Indigenous Peoples lost rights to water during colonial/post-colonial periods and are fighting to reinstate them (Wilson et al., 2021). Historical water use can resemble property rights (quasi-property rights) when these have been institutionalised over long periods, even at the expense of Indigenous People's historical rights (Bosch and Gupta, 2023).

2. **Exempt water use.** In some countries, permit exemption allows for uses of water above domestic use without a permit.

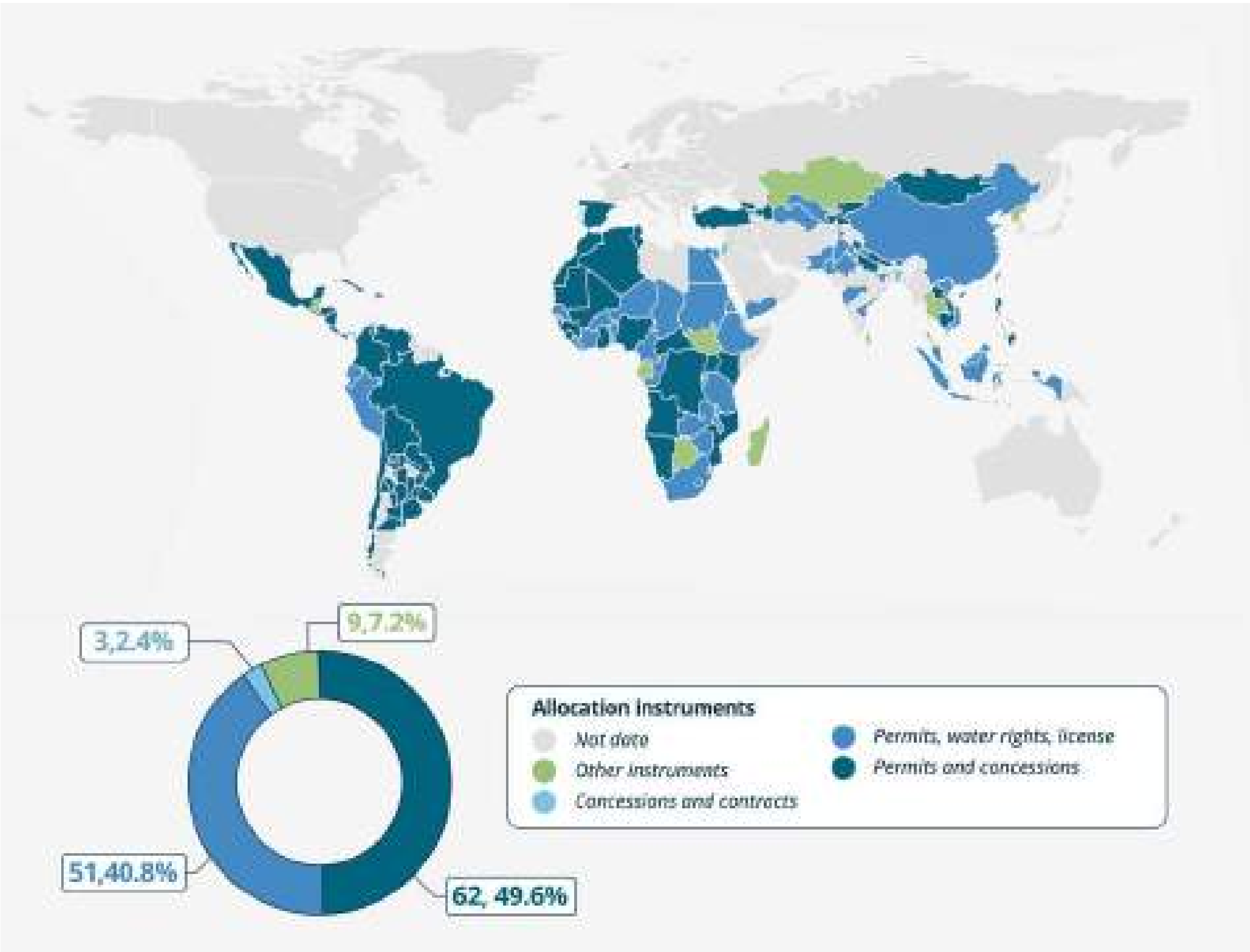
3. **Water-use permits.** For some actors, including farmers and industry, water-use permits tend to be the main water allocation instrument (see figure 6.1, Water allocation through permits, a global overview) (Bosch et al., 2021). Water-use permits can resemble property rights as permits can grant the right to use water, transfer it, protect it legally, and claim compensation in some cases, making these rights like property rights.

4. **Contracts, leases, and concessions**: For actors such as water utilities and power plants, contracts, leases, and concessions are the main water-allocation instrument, which can grant private actors quasi-property rights to water.

5. **Investor-state contracts.** These contracts often include water rights as part of broader agreements for mineral, petroleum, and land contracts. Under such contracts, water rights are treated like property rights, such as the right to use water or develop water infrastructure, and bypass a state's water law that would typically govern these uses, especially when protected by international investment agreements that limit state interference or require such a degree of compensation that states cannot withdraw permits easily (Bosch and Gupta, 2022).

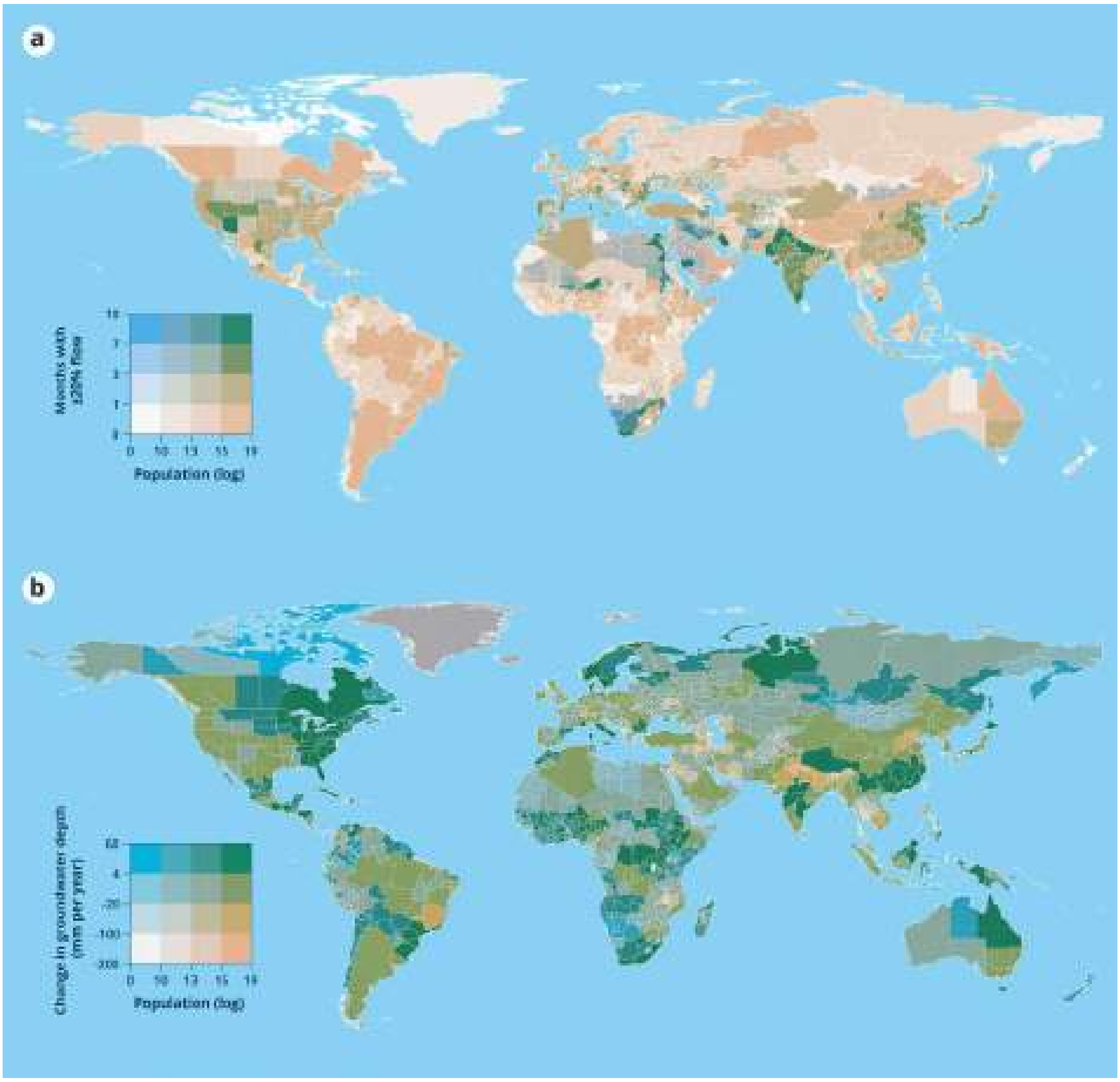
This section examines two main problems with how water partnerships have been designed – over-allocation and inequitable allocation – focusing on water-use permits, contracts, leases and concessions, and investor-state contracts.

FIGURE 6.1: Water allocation through permits, a global overview



Source: Müller et al, 2024.

FIGURE 6.2: Water fluctuation and groundwater trends compared to population



Notes: (a) Population exposed to conditions outside the safe Earth system boundary for surface water, by sub-national region. **(b)** Population exposed to different trends in groundwater depths, by subnational region. Living in conditions outside the safe Earth system boundary for blue water can impact the health, livelihoods, and well-being. Each colour represents the intersection of distributions using quartiles.
Source: Gupta et al, 2024.

Water is overallocated

In most countries and regions, the Earth system boundary for surface water has been breached (Rockström et al., 2023: 107) (Figure 6.2).[43] Groundwater levels are declining in 47% of areas, while 34% of surface-water bodies experience fluctuations greater than 20%, indicating they are outside the Earth system boundary and implying they are overallocated (Rockström et al., 2023, 107).

While some regions still have water available for allocation, in others, basins are "closed", meaning little to no water is left to be allocated (Gleick & Palaniappan, 2010; Maxmen, 2018; Molle et al., 2010; Venot & Courcier, 2008). In South Africa, numerous water management areas are facing over-allocation, with some exceeding their water resources by up to 120% (Turton and Botha, 2014). This leaves limited space to pre-empt property rights to water granted through permits and investor-state contracts.

43 The Earth system boundary for surface water is defined as a 20% alteration (increase or decrease) of monthly surface water flows compared with the prevailing natural flow regime.

Where water remains available, governments can use permits and contracts allowing allocation in the public interest and preventing the development of property rights to water, and design principles for pre-allocation with justice at their core (Bosch, 2023). However, there is limited space for water pre-allocation in many regions, as much of the water has already been allocated. In such situations, governments might consider more-radical measures, such as the renegotiation of permit and contract conditions. For new projects, there must be an understanding of where needed water should come from and what the trade-offs are between its different uses.

Water is inequitably allocated

The definition of a water right as a property right is determined by legislation and case law (Dellapenna, J. W. 2021). While most states avoid referring to water as property (Dellapenna & Gupta, 2021), various legal water-use entitlements can imply quasi-property rights, achieving the same ends through different means. States often end up privatising water de facto by allocating property-like rights through water-use permits, licenses, or contracts (Bosch et al., 2021: 12; Bosch and Gupta, 2022). These rights include, for example, the right to use water for a specified period, the right to alienate or transfer the permit, the right of legal action, the right to compensation, and the right to have their interest protected by the state.

It will be difficult for states to take water back, as some countries allow permits for 75 years. This reduces the ability and flexibility of the state to reallocate water if necessary. Some countries allow for compensation and litigation if permit conditions are changed, which also reduces states' flexibility and could lead to "policy freezing" (Bosch et al., 2021: 12).

Some jurisdictions have explicitly (e.g., Chile, the United States [US] state of California) or implicitly (e.g., South Africa) introduced a tradable permit system, meaning that water is not returned to the state. Problems arise if the original allocation was unequal, including cases where water rights were initially taken from Indigenous Peoples in the transition from a riparian-rights system to the adoption of a market for trading water licenses.

Some countries have taken a different course. New Zealand granted the Whanganui River the legal rights of a person, recognising the Indigenous Māori Whanganui Iwi's relationship with the river, and their historical rights to the land and waters. This legal framework ensures the river's protection and sustainable management, representing a pioneering approach to water justice that acknowledges both ecological and cultural values (Talbot-Jones and Bennett, 2022).

The issue of de facto privatisation of water resources can be particularly marked in the case of investor-state contracts, where overarching investment regimes can trump water regulations. Foreign investors specifically enjoy protection against state interference through thousands of bilateral, multilateral, and plurilateral investment treaties designed to safeguard the investor. Research on energy, mining, land, and water investor-state contracts reveals that water rights are explicitly included in most mineral, petroleum, and land contracts, protected by investment treaties against actions of the state (Bosch and Gupta, 2022). Taking back the right to use water infringes on the operation, which can be seen as indirect expropriation and can lead to compensation claims. This reveals that contracts and investment treaties to protect investors from state actions make it difficult for governments to redistribute water in the public interest.

Redesigning water contracts using a justice-based allocation framework

Redesigning water contracts represents a high-leverage opportunity to rethink the relationship between public, private, and other non-state actors.

To reflect the different hydrological contexts governments face, principles need to distinguish between allocation where water is over-allocated and where it is not.

Allocation principles where water is over-allocated include:

- **Evidence-based decision making.** There must be clarity about how much water any new project requires and how much it will pollute – hence the kind of user permit and pollution permit it requires. An environmental impact assessment including blue and green water impacts must be conducted.

Box 6.1: Water allocation through the lens of water system justice (Gupta et al., 2024)

Governments can be guided by allocation principles using in a justice framework (Chapter 4) when designing water permits, contracts, and land-based property rights, to embed justice at their core and ensure outcomes are efficient, equitable, and environmentally sustainable.

Recognition justice

The origins of water law and governance can be traced back 5,000 years (Gupta & Dellapenna, 2009; Dellapenna & Gupta (eds) 2021). Water allocation systems have governed water for centuries; however, conventional water allocation systems – often imposed by colonial and post-colonial legal frameworks – have historically excluded Indigenous and local water-governance practices. Permits and contracts based on the principles of recognition justice respect, protect, and cause no harm to these systems. Recognition justice calls for legal and institutional frameworks that incorporate 'other' knowledge systems, such as those of marginalised local communities and Indigenous Peoples, and their governance practices, ensuring that water allocation respects the sovereignty and self-determination of these communities.

Epistemic justice

Epistemic justice requires understanding other ways of knowing and other knowledges with respect to water. This can often conflict with state allocation of water, which when applied, is largely a calculation, modelling, and forecasting exercise. In this pragmatic and rational approach, measurement and data aim to achieve efficiency in water use and optimal water allocation. However, this process largely ignores other forms of knowledge. While it is difficult to imagine a state-led system without a government department organising water allocation, the knowledge used in the process can be improved, in part by connecting other water knowledge systems with contemporary scientific understanding.

Interspecies justice and Earth system stability

Allocating water based on a water budget considers human needs, ecosystems, and biodiversity as the basis and priority according to which water resources are allocated. Permits and contracts are therefore subject to the needs of nature, which means leaving enough green and blue water for other species and ecosystems to flourish.

Intergenerational justice

Permits and contracts should accommodate change, ensuring that the present generation preserves the hydrological cycle for future generations. This means groundwater tables should not decline, and surface-water bodies should be maintained. Hence, permits should be adaptable to enable maintaining water bodies and flows for future generations. It cannot be that rivers runs dry because permit holders continue to use their allocated volume of water without considering sustainability.

Intragenerational justice

Permits and contracts are subject to the current water budget. With a changing hydrological cycle, persistent inequality and changing socio-economic conditions, permits should ensure equitable access and allocation of resources. In considering the 3I's of relational justice – Interspecies, Intergenerational, and Intragenerational – determining which uses and users get priority over others is key and should be made explicit in the permit conditions. Within institutions, this should be clearly specified and fully operationalised.

Procedural justice

Procedural justice is about including multiple actors in decision-making about water allocation. Including local communities, Indigenous Peoples, and nature representatives (to name a few) in the process of water allocation is crucial to ensuring a more collaborative and broad-based approach. Procedural is also about allowing people who are dissatisfied to object publicly and to go to court if necessary.

- **Resource sustainability.** There should first be a moratorium on additional water allocation. Before use permits are given, the state needs to consider from which existing permit, concession, or property right water can be withdrawn.

- **Fairness.** This might require the new users to compensate existing users for the economic losses, subject to state approval.

Allocation principles where water is not yet over-allocated include:

- **Priority of use and users.** This determines which use or user gets priority over other use or users in a society.

- **Risk and reward**. This ensures that both risks and rewards are shared between economic actors, and that governments and other actors are recognised for the risks they take in shaping water-related and other markets.

- **Public interest use.** This considers the efficient and beneficial use of water in the public interest, considering its socio-economic impact. This can include the likely effect on the water resource and on other water users. Water-use permits are subject to return to the state on grounds of public interest in situations of water scarcity, and changing environmental and economic conditions. Unused water permits are the first category of water permits that should be reclaimed. Actors should be able to claim compensation (which can be zero).

- **Pollution.** This ensures that the right to use is accompanied by the responsibility to limit pollution based on the polluter pays principle. Use permits are accompanied by pollution permits. Pollution permits set allowable limits on the thermal, chemical, and physical pollution of water based on best available technology standards and ambient water quality standards. Where pollution has been caused, polluters must be held accountable or liable.

Shaping water allocation and access through conditionalities

Taking inspiration from the allocation principles, governments can use conditionalities as a concrete policy tool to shape partnerships. Conditionality involves creating agreements between the public and private sectors, where specific financial tools such as grants, loans or subsidies, or other deals such as permits, contracts or types of rights are contingent upon the private sector meeting requirements that contribute to public goals. For example, 80% of industrial wastewater is released into the environment without adequate treatment, despite it being a valuable resource from which clean water, energy, nutrients, and other resources can be recovered (Rodriguez et al., 2020). This is one low-hanging fruit where governments could embed clear, targeted, and monitorable conditionalities for companies to improve wastewater recycling in exchange for access to public land or government support.

Indeed, governments can use conditionalities to transform sectors and industries to align with their policy objectives or missions. In the case of water, industries such as mining, energy, and semiconductor manufacturing are highly water intensive. These industries, and agriculture and infrastructure (e.g., transport, urban development) can also affect evapotranspiration. Conditionalities can be used to improve their water efficiency and mitigate impacts on green water stocks and flows, or establish a reciprocal risk- and reward-sharing relationship, ensuring that public policy leads to broader economic or societal benefits.

Mazzucato & Rodrik (2023) identify four dimensions of conditionalities in new contracts between the public and private sectors:

- **The firm behaviour targeted.** FFor example, ensuring equitable and affordable access to products or services, directing firms' activities towards societally desirable goals, requiring profitable firms to share returns, or requiring reinvestment of profits into productive activities.

- **The nature of the conditions**, whether fixed or negotiable.

- **The mechanisms for sharing risks** and rewards.

- **The criteria for measurable performance** and monitoring.

Conditionalities for new or renegotiated water permits, contracts, and property rights

Governments can embed conditionality in water permits, contracts, and property rights to maximise public value and deliver a more water-secure world. For example, conditionalities could require:

- Improving water and land conservation, the efficiency of water use, and how much water should be returned into the system, and in what quality.
- Directing investment for water-intensive industries towards regions that are less water stressed.
- Reinvesting profits in productive business activities, such as research and development (R&D) and innovation around water.
- Reinvesting profits into watershed and water-basin conservation programs so the source is governed in a sustainable way (Mazzucato & Rodrik, 2023; Mazzucato & Zaqout, 2024).

Conditionalities can protect priority users and uses from the rent-seeking behaviour of investors, with focus on the poorest and most vulnerable. Conditions for risk- and reward-sharing offer flexibility to accommodate heterogeneous water consumption for water rights-holders. Applying conditionalities to water property rights can address embedded norms of private property rights such as "history of use" or the "use it or lose it" approach that lead to excessive water use (Dellapenna, 2023). The conditionalities can include procedures to reclaim unused water permits, which might include compensation.

Conditionalities in water permits, contracts, and property rights should be explicit and enforceable, and provide detailed standards and clear goals for all parties to promote and comply with (Gupta, J., Mazzucato, M., Bosch, H.J. (2024). These include setting requirements for adapting water-saving technologies and practices, and meeting environmental protection standards. They also include protecting the ecosystem and biodiversity from water withdrawal and wastewater disposal.

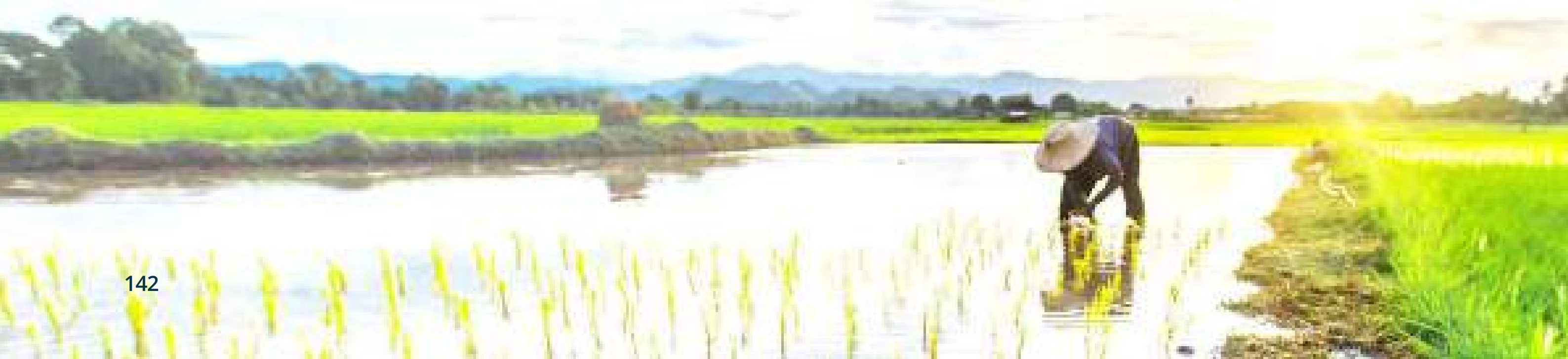
Conditionalities in water investments

Investment contracts are important to shaping water-related partnerships. In some cases, when the government partners with the private sector, the state "socialises the risks" but "privatises the rewards" of investment, leading to unbalanced partnerships that prioritise private interests over public value (Laplane and Mazzucato, 2020). There can be a strong intergenerational dimension to this: given the long-term nature of many investment contracts, such partnerships can result in future generations suffering the consequences. Conditionalities can shape investments and markets within the private sector when they take over basic services and industries such as water.

A role for private finance in the water sector requires regulatory and contractual solutions to prevent opportunistic behaviour and resource capture, such as acquiring crucial infrastructure through contracts and partnerships. Risks are often blamed for financers' and investors' short-termism, financialisaton, and high-cost debt, which push water utilities away from public value creation. Embedding conditionalities into contracts can allow private and public actors to share and thus reduce the risks of major investments – and spread the rewards, like lower operational costs for businesses and greater public value provision by governments, facilitating innovation in the private sector while directing benefits to the public (Mazzucato & Rodrik, 2023; Laplane & Mazzucato, 2020).

Just Water Partnerships

Partnerships done right have the potential to shape a more water-secure future. Arrangements like Just Water Partnerships could bring public, private, and philanthropic sectors together to make ambitious investments in water with clear conditionalities attached. Governments can bring



in financing partners by pooling smaller investment opportunities for increased bankability, utilising well-designed guarantees and co-investment setups, and enforcing the agreements facilitating these investments (GCEW, 2023a).

Just Water Partnerships allow governments to facilitate new water management paradigms that serve vulnerable communities and ecosystems. By mobilising water investments that embed justice principles, prioritise sustainable and equitable allocation, and align with the new science and economics of water – considering both blue and green water flows – governments can ensure critical water projects are designed and financed to promote socially and ecologically healthy outcomes.

On a country-by-country basis, policymakers can weave together the financial tools and institutional arrangements that best fit their specific context. In this way, countries can design Just Water Partnerships to meet their needs, addressing financing gaps to promote public value and positive water outcomes for all. Chapter 8 describes how Just Water Partnerships can deliver a safe and just water future.

Transparency, monitoring, and accountability

Embedding conditionalities requires accountability measures to ensure compliance by all actors. This includes clear legal frameworks to manage relationships with water rights holders. This also includes strengthening data collection and increasing self-reporting of the water rights holder's performance. The fragmented data landscape around water is a big hurdle. Global water data is incomplete, lacking interoperability, consistent standards and comprehensive scope. Gaps exist at various hydrological and administrative scales, and much of the data remains private or behind a paywall. This holds true for both blue and green water. Data on green water especially is frequently overlooked in data regimes and management, effectively missing half the story of the hydrological cycle. However, there are opportunities to increase water-data collection (Chapter 9), including through new technologies that expand the frequency and accuracy of monitoring, such as satellite imagery, remote sensing and AI.

A second hurdle is underreporting on corporate water footprints. The utilisation of natural resources for production is often under-reported, and mandated reporting is limited, frequently failing to cover the value chain and full life cycle of products and services. Comprehensive data on the impact of business activities on blue and green water is key to ensuring adherence to conditionalities intended to steer business activity towards sustainable and just practices, and for motivating corporate efforts to mitigate water and climate risks in their operations and supply chains. Despite these challenges, governance arrangements can be improved to strengthen the transparency of water use and accountability of water users. Momentum must be generated for disclosure of corporate water footprint, inspired by practices such as the European Commission (EC)'s mandatory Corporate Sustainability Reporting Directive (CSRD).

Explicit water-use reporting requirements should be developed and incorporated into similar directives. Disclosure mechanisms can also be considered, especially by mobilising coalitions of private sector and civil society organisations such as CDP, a not-for-profit that runs a global disclosure system for investors, companies, cities, states, and regions to manage their environmental impacts. CDP's water security programme has been particularly effective, and since 2009, CDP operates the only global corporate water disclosure mechanism. In 2022, nearly 4,000 companies disclosed water security data through CDP. Looking ahead, CDP aims to collect relevant water-related data from 90% of the world's highest-impact companies by 2025.[44] CDP has a similar programme on forests, which might provide the foundation for disclosure mechanisms that cover blue and green water.

Without effective transparency, monitoring, and accountability mechanisms around water and land use, it will be difficult for public regulators to ensure businesses comply with conditionalities stipulated in water contracts.

44 Link: Catalysing water action amongst thousands of the world's largest companies and closing the data gap. | Department of Economic and Social Affairs (un.org)

7. Finance for a just and sustainable water future

Key takeaways

Water remains vastly underfunded across the global economy. The GCEW highlights how we can substantially raise the volume of finance for water, as well as improve the quality and direction of such finance.

Far greater investments are needed to conserve both blue and green water and scale up innovations for more efficient water use across agriculture, industry, mining, and other sectors that are critical for stabilising the global water cycle – underpinned by the new economics of water advocated in this report. We should explore **how the value of green water can be recognised and incorporated in schemes for payment for ecosystem services**. Considering water as natural capital points in the same direction.

Every stream of finance — public, private, domestic, and multilateral — must be significantly enhanced. To achieve this, we must build **symbiotic partnerships that combine public, private, and other non-state actors, with appropriate sharing of risks and rewards** amongst them.

Governments need to provide for certainty in policies and regulation, and reprioritise investments in water. Pricing is essential, as the under-pricing of water has systematically weakened the case for investment. There is also an important opportunity to **reduce and redirect the massive direct and indirect financial subsidies that contribute to the overuse of water and environmental degradation**. Harmful subsidies in agriculture alone are estimated to exceed USD 550 billion. Further, the discount rates used to assess investments in water infrastructure and ecosystem preservation should take into account their long term, including intergenerational, social, economic and environmental benefits.

National, regional, and multilateral development banks must be regeared to provide the catalytic finance needed to unlock vastly greater amounts of private finance — including patient, long-term finance. They should favour programmatic, portfolio-based approaches, aligned with public policy objectives.

Just Water Partnerships should be established and tasked with the design, implementation, and financing of transition towards development strategies aligned with the water agenda. These partnerships, involving development-finance institutions and national authorities, should build capacity to mobilise investments and manage blue and green water sustainably. They should make active and bold use of the menu of instruments available to catalyse private investments. These could include first-loss guarantees, concessional finance elements for lower-income countries, and co-investment arrangements to manage risks.

There is also untapped potential to diversify risks by bundling water projects across sectors and countries, to attract finance from institutional investors.

Disclosure of how corporate activity affects – and is vulnerable to – the hydrological cycle can redirect financial flows to support the water, nature, and climate agendas. Coordinated action with financial regulators is the way forward, building on on-going dynamics in climate and nature finance.

The water community has long advocated for bridging the prevailing financing gap. This chapter emphasises the need to shift towards considering the quality and direction of financial flows as well. It advocates for moving beyond a singular and incomplete focus on blue water to incorporating both blue and green water. Paying attention to the green water part of the hydrological cycle is crucial for succeeding in climate-change mitigation and adaptation, biodiversity, and forest and wetland conservation and regeneration.

All streams of financing – public and private, domestic and multilateral – must be enhanced to enable collective action across sectors, capabilities, and scales. For example, there are major opportunities for private investment that can yield adequate returns while serving the common good in the water value chain, including water treatment and recycling, scaling up innovations across the economy to optimise water use, and growing the circular water economy. However, achieving the symbiotic partnerships needed that combine public, private, and other non-state actors will rely on transitioning from merely "de-risking" private finance to reconsidering how risks and rewards are shared among stakeholders in a just way.

In addition to its social, cultural, and economic values, water is increasingly acknowledged as a key factor for macro- and micro-economic performance. This should translate into how it is accounted for in national and corporate accounts to drive decisions, and public and private finance.

The availability of more robust water data (Chapter 9) is a requisite for changing the scale and quality of water-related finance across all streams, and enabling the use of the financial mechanisms and tools explored in this chapter.

Key financing strategies that address the water cycle's imbalance include:

- Evolving **public finance** from a project-based approach to a programmatic, portfolio-based, strategic approach aligned with policy objectives, incorporating conditionalities in financing contracts to shape markets.
- Shifting **private finance** from a separate silo to being mainstreamed; scaling-up blended finance, combining policy and social instruments to unlock critical investments for water, catered to individual countries' needs; adjusting discount rates to consider intergenerational justice; and valuing ecosystem services without commodification. Critically, water-related disclosure must be reinforced to assess both the financial and physical materiality of a destabilised hydrological cycle for countries, corporates, and financiers.
- Using **multilateral finance** to enhance the effectiveness of debt-for-water swaps, and transitioning from fragmented, project-based financing to holistic programmatic approaches within Just Water Partnerships for sustainable transitions at multiple geographical scales.

A paradigm shift is needed in how water financing is approached, to offer a comprehensive strategy that considers not only the quantity but the quality and direction of financial flows, the integration of blue and green water in financial decision-making, and the alignment of financial mechanisms with ambitious, economy-wide policy objectives and missions.

Water-related financing exacerbates justice issues

While every country faces some water-related financing challenges, emerging economies are most exposed and vulnerable to the lack of finance. Within countries, disadvantaged groups and communities are most affected by the misalignment between financial flows and water-related needs and ambitions. In the case of water supply, sanitation, and hygiene (WASH), communities not connected to public water services typically pay a higher price for lower service quality (Gulvani et al., 2005), they do not benefit from social tariffs and public support to public infrastructures, and they are most exposed and vulnerable to health issues triggered by lack of access to safe water and sanitation.

Prevailing financial mechanisms can further affect water-related justice. Massive public funds are funnelled as subsidies that can be socially regressive when they benefit agents who could afford to pay more. Moreover, when public finance's role is conceived narrowly as essentially de-risking private investment, it can exacerbate unjust allocation of capital, as it can increase public debt while securing private benefits.

Justice issues also emerge when public investment generates value that is privately captured. Flood protection is a good illustration: dikes and levees are financed by public funds but add value to property privately owned and developed. Land-value capture is a fiscal mechanism that can redress this imbalance in the allocation of costs, risks, and benefits (OECD, 2023b).

Recent examples in water-related finance have raised justice issues. Some observers caution about the financialisation of water supply, sanitation, and hygiene infrastructure where financial institutions maximise short-term profits at the expense of productive development (Arrojo-Agudo, 2021). The trend has reduced water infrastructure to a mere financial product, troubled with high risks and financial engineering to increase investment return, with little regard for its utility and capacity to address such challenges as the uncertainty of climate change and the increasing inequalities in access to water (O'Neill, 2015). Investors can move towards long-term growth investments when the right regulatory framework is in place (Chapter 8).

An enduring financing gap

Multiple sources attempt to characterise financing needs and flows for water. They differ in scope (most focus on water supply, sanitation, and hygiene while flood protection and other domains are poorly documented), geographical coverage, methods, and time horizons. Definitions vary, making comparisons challenging. A major discrepancy regards how climate change is factored in, if at all (WWC-OECD, 2015). None reflect the consequences of a destabilised hydrological cycle.

Still, some orders of magnitude stand out. Investment needs to meet United Nations (UN) Sustainable Development Goal (SDG) 6 are three times what has been historically invested in the sector (Hutton & Varughese 2016). These projections only cover access to safe water and sanitation (Targets 6.1 and 6.2). They include neither hygiene nor requirements for operation and maintenance of infrastructure. They do not consider financing required for water to contribute to other SDGs. Regional disparities are significant. Further, the latest studies indicate that the annual investment gap for achieving SDG 6 alone in low-income countries is about USD 500 billion for 2023-30. This includes investment in water sources (such as new water-treatment and desalination plants), sanitation facilities, and wastewater management (UNCTAD 2023). These investments have to be viewed not as a cost, but as spending needed to derive significantly larger economic and social returns.[45]

Much larger additional investments are needed to address climate change and its potential impact on the water cycle, to conserve water and scale up innovations that enable more-efficient use of water in agriculture, industry, mining, and other sectors critical to stabilising the hydrological cycle.

45 WaterAid. 2021. *Mission-critical: Invest in water, sanitation and hygiene for a healthy and green economic recovery*.
Hutton. 2015. *Benefits and Costs of the Water Sanitation and Hygiene Targets for the Post-2015 Development Agenda*. Copenhagen Consensus Center, Post-2015 Consensus Initiative.

Water-related finance is affected by several limitations. First, public investment in water has been a low priority for many governments, in both high- and low-income countries. Many take a short-term and reactive approach to water infrastructure, leading to neglected assets, frequent service disruptions and leakage – culminating in higher long-term costs. Incoherence in policy interventions and investments contributes to investment gaps (CEEW-IWMI, 2024; Taneja et al., 2023). This translates into disparate efforts between interdependent water, energy, and food systems, further widening the investment gap.

Data from emerging markets show that only 9% of finance for water supply, sanitation, and hygiene comes from the private sector, as opposed to sectors like telecoms and energy, where private capital makes up 87% and 45% respectively (WaterAid, 2022). The Word Bank reports an even lower contribution of private finance for water supply and sanitation (WSS) in 113 low- and middle-income countries, at 1.7% (Joseph et al., 2024).

Second, while most water-related projects are long-lived (dams or dikes), megatrends in climate change, demographic and social changes, globalisation, and digitalisation are poorly understood and reflected in financing water (OECD, 2019). This leads to quantitative and qualitative misalignment of water and finance. It can also lead to maladaptation and additional financing needs in the future. For instance, investing in large-scale, single-crop agriculture in regions where total water storage is projected to decline (Chapter 3) can increase dependence on blue water and trigger needs for additional investment in dams, reservoirs, and irrigation.

Third, where infrastructure has been built, operation and maintenance costs are often underestimated (WWC-OECD, 2015), and cost-recovery is low. Lack of attention to proper operation and maintenance leads to a vicious cycle of poorly operated infrastructure delivering sub-par services and decaying rapidly, magnifying future investment needs to rebuild them. This is not limited to water supply, sanitation, and hygiene – cost-recovery for irrigation is even lower (OECD 2022a) – and it is an issue in both high- and low-income countries.

Distinctive features of water-related investments explain why private investment in the water economy has been scarce, and almost absent in low-income countries (Leflaive et al., 2022). Before we list them, it is worth noting that some water-related investments do attract private finance at scale, including large facilities to supply water and sanitation services; desalination plants; and dams for water storage, hydropower generation, or multiple purposes. In these domains, the priority should be to crowd-in private finance, with minimal use of public or development finance.

Other domains have been particularly unable to attract private finance, notably flood protection, nature-based solutions, small-scale infrastructure, and rural water supply and sanitation. Financing models in these domains fail to scale up. Distinctive bottlenecks include (OECD 2022a):

- Disproportionate transaction costs
- Lack of standardised financing modes and instruments
- Fragmented nature of small-scale water-related investments
- Unstable or inconsistent regulations failing to reduce risks, even for patient investors
- Absence of sound regulatory frameworks in many geographies, leading to a persistent non-alignment of the interests of investors, water entrepreneurs, and society to leverage more capital into the water sector (McCoy & Schwartz, 2023).

The under-pricing of water across sectors and geographies weakens the case for investment. Low tariffs and misdirected subsidies increase the fiscal burden in many countries.

From quantity to quality, to close the financing gap

To tackle the global water crisis, we must focus on both bridging a large quantitative financing gap and adopting a qualitative emphasis in structuring water finance. This section characterises the type of finance needed to meet water policy objectives, and the role of governments and public development banks in providing patient, directed finance with positive spillovers throughout the economy. It provides a new perspective on sharing risks and rewards. The section highlights five principles to guide finance for a safe and just water future at multiple geographical scales.

Patient, long-term and directed finance

Mission-centred policy (Chapter 4) requires the right type of finance. Due to inherent uncertainty and lengthy development phases, financing innovation, infrastructure, and other economic activities in the water space requires a unique balance of risk and reward. Finance must therefore be patient and long-term; loans should preferably be in local currencies.

Governments play an important role in providing patient, long-term finance (Mazzucato & Macfarlane, 2018; Lazonick & Mazzucato, 2013). Finance must be directed towards addressing agreed missions with clearly defined outcomes and goals – not merely financial and budgetary allocations to certain sectors, types of firms, or technologies. Water-related missions involve sectors as diverse as infrastructure, transportation, agriculture, energy, and technology, among others. By investing in a direction and crowding-in multiple sectors, there is an opportunity to incentivise investment that would not happen otherwise (Mazzucato, 2023b; UCL-IIPP, 2020). For example, investing in grey water infrastructure can lead to multiplier effects such as health benefits, access to clean drinking water, and recycling water in agriculture, leading to more jobs and higher productivity (WaterAid, 2021). Tackling a challenge like resilience against extreme weather events requires solutions beyond grey water infrastructure – early warning systems, rainwater harvesting at landscape scale, permeable pavement, bioswales – to engage innovations and markets that can mobilise public and private investment, leading to larger multipliers.

Moving from a focus solely on filling water financing gaps to directing finance and shaping markets requires a new set of principles.

Principles for financing water

Five principles should guide policy, regulation, international co-operation, and private investment to direct the right quantity and quality of finance towards water:

1. Recognise the science
2. Recognise that water justice issues range from local to global levels
3. Value blue and green water as natural capital
4. Share risk and rewards to unleash private investment
5. Get discount rates right

First, recognising the science means realising that the hydrological cycle is a global common good, and is out of balance. We also need to recognise and leverage water, land, and ecosystems owed to green water. Markets – including financial ones – can be shaped to direct financial flows towards stabilising the hydrological cycle and away from further destabilising it. In addition, we need to understand the sociocultural and political nature of water worldwide, and how societies have respected, used, abused, and allocated property rights to water resources (Bosch et al., 2021; Bosch and Gupta, 2022).

Second, we must recognise that water justice issues range from local to global levels (Gupta et al., 2023; Gupta et al., 2024). Universal access to safe and affordable water is a societal imperative within countries and a foundation of solidarity globally. Financially sustainable models for water infrastructure are needed so that water services and protection against water risks reach the poor. This would involve reforms in water pricing and how subsidies target the poor and underserved rather than going to the privileged. Cheap water and social tariffs benefit only households connected to water services; they do not benefit the poorest, unconnected communities, and they deprive service providers of the revenues needed to extend service coverage.

Third, we must value blue and green water as natural capital: a critical resource that provides valuable services for economies and societies. Pricing water accordingly could offer revenue streams and deliver significant benefits to countries over time, a requisite for attracting financiers. Considering water a critical resource need not lead to commodification. On the contrary, it recognises the value water contributes to such public benefits as ecosystems services, livelihoods, and sustainable development.

Fourth, we must ensure an appropriate sharing of risks and rewards to unleash private investment. There is substantial scope for the participation of private investors in the water sector, and water conservation and circular use across the economy. Private participation in infrastructure development is more common in high-income economies, as their capital markets and institutional environments are more stable. Risk and reward sharing via robust regulatory structures can stimulate more-patient private investment.

Finally, it is critical to get discount rates right, as they signal the projected value of long-term benefits in today's financing decisions.

Applying these principles to the five critical water missions set out in Chapter 5 can achieve the needed scale and directionality of investment.

Policy shifts to move the needle on water finance

We highlight the shifts in public, private, and multilateral finance required to align finance and investment with the water agenda defined in this report.

Public finance

The role of governments in creating enabling environments

Enabling conditions can minimise transaction costs, which are significant bottlenecks for water-related finance, especially when it comes to water efficiency and demand management, nature-based solutions, or small-scale projects. Governments have a role to create enabling environments through a combination of regulatory certainty for co-investment by non-state actors, and direct co-investment in technologies, skills, and infrastructure.

The OECD characterises four dimensions of an enabling environment for investment in water security (Sanchez Trancon et al., 2024). Such a characterisation might need adjustment to embrace the hydrological cycle.

The role of national development banks to direct patient finance

Governments cannot just facilitate, enable, and de-risk private finance to steer economies towards

Box 7.1: Four dimensions of an enabling environment for water finance

The four dimensions of an enabling environment for water finance identified by the OECD come with a scorecard to review the state of play at national level:

1. *The overall policy framework for investment. The first dimension aims to assess if the country is attractive for investors in general.*
2. *The water policy framework for investment. Water-related policies can help water projects create value and attract investment, particularly if part of that value can be transformed into a revenue stream. Water projects that can attract investment will need to demonstrate a robust business model, generate stable revenue streams, and minimise risks (OECD, 2022).*
3. *The capacity to develop bankable and sustainable projects. This dimension assesses institutional set-up, mandates, policies, and regulations. Project bankability relates to size, revenue streams, business model, risk-return profiles, return time. While financiers typically advocate for pipelines of bankable projects, government authorities should promote broader strategic investment pathways that are resilient and contribute to water policy ambitions over the long term and at least cost.*
4. *How water features on the agenda of economic sectors. Investments in agriculture and food, energy and climate resilience, urban development, and other domains can have significant unintended consequences on the hydrological cycle, and on exposure and vulnerability to water risks. An enabling environment must ensure that investments in these domains contribute to rather than undermine water policy objectives. Assessments are particularly appropriate during the ideation and investigation phases.*

Source: Sanchez Trancon et al. (2024).

the efficient, equitable, and environmentally sustainable management of blue and green water. They must actively shape and co-create markets to achieve the five critical missions set out in Chapter 5.

In many countries, patient, strategic finance comes increasingly from national development banks (Mazzucato, 2023b). Due to their mandates and stable sources of funding, these are appropriate partners for the private sector to co-finance riskier water projects. Banco Desarrollo del Ecuador, BNDES in Brazil, Banco Nacional de Obras y Servicios in Mexico, Caisse de Depot et de Gestion in Morocco, and the Development Bank of Southern Africa are among those increasingly providing loan, grant, and equity funding for water projects (Finance in Common, Crespi 2021; Reghizzi, O. et al. (2022). Considering green water could be the new frontier.

How finance is structured matters. India's National Mission for Clean Ganga employs a hybrid annuity model for water infrastructure projects, wherein the government pays out the bulk of construction costs over a 15-year period, contingent upon the performance of wastewater collection and treatment services (Global Infrastructure Hub, 2022).

There are opportunities for more national development banks to adopt mission-oriented mandates aligned with the SDGs. Germany's national development bank, KfW, aligns its financing with three "megatrends"; the Scottish National Investment Bank directs its funding towards three missions: (1) Achieving a just transition to net-zero carbon emissions by 2045; (2) Extending equality of opportunity through improving places by 2040; and (3) Harnessing innovation to enable Scotland's people to flourish by 2040. Adopting water-related missions in line with those set out in Chapter 5 could be equally promising for national development banks. This would also include shifting from programmatic approaches that dominate development bank operations to portfolio-based approaches aligned with key priorities. As a result, all direct and indirect finance mechanisms become aligned with these priorities as well.

Embedding conditionalities to share risks and rewards

Critical to delivering direct finance is designing relationships with the private sector and other non-state actors that share the risks and resulting rewards. If governments and public sector institutions are the drivers of patient, long-term, and high-risk finance, sharing the rewards and the risks is at the heart of more symbiotic partnerships between the public and private sectors.

Conditionalities are one policy tool governments can use. Governments can embed conditionalities in contracts to, for example: (1) improve water conservation and the efficiency of water use; (2) direct investment for water-intensive industries towards regions that are less water stressed; (3) reinvest profits in productive business activities, such as research and development (R&D) and innovation around water; or (4) reinvest profits into watershed and water basin conservation programmes so the source is being governed in a sustainable way (Mazzucato and Rodrik, 2023; Mazzucato and Zaqout, 2024).

Governments can use conditionalities to transform sectors and industries so they align with public policy objectives. In the case of water, industries such as mining, energy, and semiconductor manufacturing are highly water intensive. If the government's objective is to change over-consumptive use of water, conditionalities can be used to improve water efficiency.

Efforts can also be made to design Just Water Partnerships using conditionalities (GCEW, 2023a; see below).

Private finance

Making water investments viable and just

Blended finance offers the option of using catalytic (public) capital to act as a risk-reducing mechanism and mobilise private sector investment. Despite its attempts to structure and right-size risk through different types of capital, blended finance remains under-utilised for water-related projects. Between 2012 and 2017, only about 1.4% of private finance mobilised through development finance was dedicated to the water supply and sanitation sector (OECD 2022a).

A range of solutions is needed to diversify and expand financing options, catering to individual countries' needs. These include:

- **Strengthening data architecture** (Chapter 9)

- **Creating an enabling environment** to support innovative financing solutions (see above)

- **Developing the capacity of stakeholders** in the blended-finance ecosystem, including the public, private, and philanthropic sectors

- **Developing a pipeline of bankable projects** that generate sustainable benefits for communities and the environment

- **Learning from the success of other infrastructure sectors.** For example, the water sector could adopt a policy instrument like the feed-in tariff designed to support the development of renewable energy sources. This guaranteed, above-market price for power producers provided certainty and reduced risk for new renewable-energy installations. After a period, feed-in tariffs were wound down because financiers became more comfortable with the risks of the sector and the finance pool grew substantially.

- **Adopting social instruments such as offering incentives to communities.** Communities can be engaged and rewarded for their efforts as citizen-scientists for water-quality monitoring. Such intervention will need investments for capacity-building. The creation of a "social fund" from the revenue of a project can provide base access for the poor, and other social benefits.

- Despite low uptake, there are examples where blended finance helped ensure more equitable access and distribution of water, and addressed the needs of the poorest and most vulnerable (see examples in Leflaive et al., 2022; Box 7.2).

Box 7.2: Examples of blended finance by municipalities, corporates, and governments

A pooled municipal-bond issue to help small providers access private finance

In India, providers had been held back from accessing private finance by a lack of credit ratings or ability to cover bond issuance costs and legal fees. The State of Tamil Nadu created the Water and Sanitation Pooled Fund (WSPF) in 2002 to help 13 small- to medium-sized Urban Local Bodies (ULBs) finance water supply and sanitation services by accessing long-term domestic capital markets.

The AA-rated bond for USD 6.2 million had a coupon of 9.2% per annum and a maturity of 15 years. The debt was repaid through general ULB revenues. Investor confidence was ensured through five credit-enhancement mechanisms:

1. *State government debt-service reserve fund (DSRF): 1.5 times annual principal and interest payments*
2. *ULB escrow accounts: revenue accounts to pay annual debt service obligations early*
3. *Local debt service reserve fund: 5% of the principal borrowed by each ULB*
4. *State revenue intercept mechanism*
5. *Partial credit guarantee: provided by the US Agency for International Development (USAID) to pay 50% of the principal through the through the DSRF in the case of default*

Source: World Bank (2016a)

Water Access Acceleration Fund

The Water Access Acceleration Fund (W2AF) is a private-equity, water-focused, blended-finance, impact fund by Incofin,[46] which was announced in the lead-up to the UN 2023 Water Conference. The fund invests in innovative water businesses that provide affordable, safe drinking water to underserved populations.

46 Incofin is a leading emerging-markets-focused impact-investment-management firm specialised in financial inclusion, agri-food value chain, and access to water. Founded in 2001, Incofin has invested (via equity and debt financing) over EUR 2.7 billion in more than 320 investees, financial institutions, and SMEs in the agri-food value chain across 65 countries in Asia, Africa, Latin America and the Caribbean, and Eastern Europe.

It seeks to mobilise patient capital in innovative, early- to growth-stage businesses along the water access value chain to achieve this objective.

USAID provided USD 760,000 as concessional catalytic funding for its first loss tranche, conditioned on Incofin raising four times the amount of capital from private sector investors.[47] *This commitment from USAID helped W2AF derisk the fund for private investors, building momentum for the fund's first close. W2AF hit EUR 51 million in commitments at this first closing and aims to achieve total capital commitments of EUR 70 million in subsequent closings.*

The first investment by Incofin's W2AF was in Rite Water Solutions (India), which has raised EUR 7.5 million and provides potable water and water-quality-improvement services in areas where water sources are chemically and biologically contaminated. Incofin also invests time and effort to educate private investors about the investment readiness of the water sector, allowing investors to better assess the risk in a sector they would have traditionally shied away from due to lack of knowledge and perception of high risk.

Brazilian water utilities

The Brazilian water market is transforming to meet societal needs, with private investors bidding to take over poorly managed and loss-making municipal water concessions. A long-term (30-35 years) concession approach has attracted significant investments.

Tariffs are fixed, with inflation adjustments only.[48] *Private investors capture full upside from cost-cutting and other efficiency improvements. As such, the concession is incentivised to invest to deliver the pre-agreed service levels and improve efficiency (i.e., reduce leakage, which increases costs). As early CAPEX often means faster revenue growth and lower operating costs, the operator has flexibility to upgrade the network seeking improvements, to invest in more efficient equipment, and to introduce extensive monitoring and automation to reduce costs.*

Municipality concession auctions aim to expand coverage in poor areas, improve quality of service, and reduce environmental impact. Poor communities, often deprioritised in pre-privatisation investment programs, are now the most positively impacted. Illegal tapping is replaced by formal connections with subsidised prices, reducing losses and leakage. To date, concessionaries have delivered major investments without real tariff increases.

We must address the need to make water investments attractive to the private sector across the economy. Strained public finances add urgency to doing so. It means shifting from thinking of public and private finance as siloes, towards mobilising total finance on a much larger scale through regulatory reforms and appropriate sharing of risks and returns.

Valuing water as natural capital

A natural-capital approach considers nature as a stock that provides benefits to people and the economy. Recognising the value that nature provides can encourage investment in its protection and restoration. This shift in perspective, from seeing nature as free, to valuing ecosystem services, creates a mutually beneficial outcome: businesses can invest in sustainable practices that benefit the environment while generating financial returns and safeguarding the resources on which they depend (see case studies in Leflaive et al., 2022).

47 Investors in the fund include Danone, Aqua for All, the US International Development Finance Corporation (DFC), Norfund, Investment Fund for Developing Countries (IFU), BNP Paribas, and several other private investors.

48 Once awarded, the tariff is no longer subject to periodic regulatory reviews but is fixed for the whole concession period (except for the allowed annual inflation adjustment). This provides certainty to the bidder on what returns to expect during the life of the concession based on its business plan.

Box 7.3: Water as natural capital provides economy-wide benefits

The linkage between forests and hydrology is complex. Nevertheless, under certain conditions, reforestation can improve water quality through a reduction in soil erosion and prevention of nutrient-rich agricultural runoff draining into freshwater bodies. Assessment undertaken in Tietê Basin, Brazil, which supplies water to the São Paulo megalopolis, suggests that the increase in water availability through enhanced water quality is the greatest benefit of reforestation as a strategy to improve water-related ecosystem services in the region (Ferreira et al., 2019). Similarly, protecting wetlands such as tanks, ponds, and lakes can ensure the provision of multiple-use water services, which include water for irrigation, domestic needs, fisheries, and recreational uses; improve groundwater recharge; and contribute to flood control and silt capture (Bassi et al., 2014). It can also enhance the resilience of urban areas to climate change.[49] Tourism around wetlands can make a significant contribution to a nation's economy and employment (Bassi et al., 2014). These examples illustrate how investing in natural capital (forests, wetlands) delivers benefits across the economy. Factoring in the contribution of ecosystems to green water stocks and flows can strengthen the economic case for their protection.

Valuing water as natural capital is in its early stages, with much work ahead. It is an important enabler for responsible stewardship of freshwater ecosystems and decision-making on land-use changes. Standards are being developed by several coalitions such as the Alliance for Water Stewardship, the Capitals Coalition, and the collaborative initiative between the UN Environment Programme World Conservation Monitoring Centre (UNEP-WCMC) and other stakeholders on a Toolkit for Ecosystem Service Site-Based Assessment (TESSA)(see also Chapter 9, on data).

Four courses of action can support development and apply beyond water, sanitation, and hygiene. Considering the green water part of the hydrological cycle, domains that affect land use are particularly relevant, such as food and agriculture, industry, and urban development.

The first course of action consists of monetising cashflows from the provision of ecosystem services. Payment for ecosystem services (PES) for watershed conservation remains dominated by the public sector. The key to unlocking commercial investments in natural capital is to demonstrate a link between investment upstream and benefits for users downstream. Green water credits deserve particular attention (Box 7.4).

Box 7.4: Reviving green water credits

Green water credits are designed to promote and finance green water management as a solution to increase productive transpiration, reduce soil surface evaporation, control runoff, encourage groundwater recharge, and decrease flooding. As defined by ISRIC, green water credits are a financial mechanism that supports upstream farmers to invest in improved green water management practices. Those farmers will benefit directly, but the benefits might not be sufficient to compensate for their investments. Therefore, a green water credit fund must be created by downstream private and public water-use beneficiaries. Initially, public funds might be required to bridge the gap between investments by upstream land users and the realisation of the benefits by those downstream. Pilots were initiated in China, Kenya, and Morocco two decades ago, bringing together users in the design, implementation and financing of proper landscape management.[50] Green water credits combine three perspectives to unlock finance to conserve catchments such as tropical forests, and to stimulate transition towards sustainable land use at landscape scale, namely: (1) a landscape (regional) transition perspective; (2) a farm-level perspective; and (3) the perspective of financial investors (Rode et al., 2019). There are opportunities to reshape that mechanism and make it a tangible connector between watershed users, in line with the five critical water missions highlighted in this report. At national, regional, or global levels, it seems appropriate to explore how market mechanisms can be designed to compensate others for contributing to rainfall.[51]

49 *Water as Leverage* provides multiple examples, guided by eight project lifecycle principles. https://english.rvo.nl/subsidies-financing/water-leverage

50 https://www.isric.org

51 https://naturexclimate.substack.com/p/a-new-market-or-non-market-mechanism

In the second course of action, on-going work should be leveraged to measure, value, and account for nature (including water), such as the Natural Capital Protocol, the Taskforce on Nature-related Financial Disclosures (TNFD), the Valuing Water Initiative, the International Sustainability Standards Board, and the Science Based Targets Network (SBTN), which is developing water targets for corporates, alongside other dimensions like biodiversity and land degradation. Other efforts include the Taskforce for Climate-Related Financial Disclosures (TCFD) and the Climate Disclosure Standards Board (CDSB), which help companies provide better information to support market transparency and informed capital allocation. Water has been a part of these initiatives, and a substantial number of companies or government bodies have already accumulated experience in this area.

Third, sustainability-linked bonds can be used more systematically to finance water projects. One such instrument is the European Investment Bank's (EIB) Sustainability Awareness Bond (SAB). It is a use-of-proceeds bond that utilises the funds raised through the issuance of SABs to finance water and wastewater projects that meet the bond criteria. Such bonds are classified into green, social, and sustainability bonds and reached almost USD 1 trillion in 2021 (OECD, 2023b).

Fourth, social instruments, such as incentives for a community to protect water ecosystems, can improve water security and services. One example of the use of social instruments is flood management in Indonesia using nature-based solutions. As a part of the Zurich Flood Resilience Alliance, a results-based financing mechanism was developed to support the implementation of nature-based flood resilience projects. The mechanism included community-based cash-for-work projects for mangrove planting, river swales for stormwater management, and wetland rehabilitation (Molnar-Tanaka & Surminski, 2024). Similarly, there is scope to mobilise more climate finance for water-related investments. This report argues that protecting green and blue water can mitigate and support adaptation to climate change, making a case for such projects to qualify for the Green Climate Fund (GCF), for instance.

Getting discount rates right

Discount rates in cost-benefit analyses give a lower value to benefits that accrue after longer periods, and thus disincentivise long-term investments. Getting discount rates right[52] for water infrastructure projects, especially over longer time horizons (also called intergenerational discounting) will address the impacts on and preferences of generations to come. Ideally, discounting should be based on the rate at which society is willing to postpone water consumption and land-use change today for consumption in the future (USEPA, 2010). This will yield both societal and environmental benefits. Shifting from static multipliers to more dynamic evaluation methodologies can help governments quantify the multiplicative effects of strategic and mission-oriented public investment into water.

Incorporating the materiality of water risks

While water regulators can encourage more efficiency in water withdrawals and consumption, financial regulators have a role in monitoring corporates' and financial institutions' dependency on water, and the water-related impacts of their supply chains or portfolios.

There is growing awareness of the economic and financial impacts of water risks, with emerging evidence suggesting potential implications for financial stability. In July 2024, Moody's flagged that rising water risks could amplify credit pressures across a range of sectors, and that water management will play an increasingly important role in tempering growing exposure to physical climate risks, as climate change exacerbates water scarcity and hazards.[52] While central banks and financial institutions have yet to fully capture water-related risks in their risk assessments, the financial sector's material exposure to water-related risks is increasingly recognised, with the potential for macro-economic impact (Davies & Martini, 2023).

Davies & Martini (2023) examine the financial sector's understanding of water risks and their materiality. Practice shows that water risks are not fully captured by existing risk-assessment approaches. To address this, better tools, data, and proactive engagement are needed. Initiatives such as the Network for Greening the Financial System (NGFS) and the Taskforce on Nature-related

52 https://www.moodys.com/web/en/us/about/insights/infographics.html

Financial Disclosures (TNFD) offer frameworks to consider water-related climate and nature risks across the financial sector.

The overarching goal of future work should be to develop a framework for policymakers and financial supervisors to understand, identify, and assess water risks, taking account of the full hydrological cycle. More work is needed to develop regulatory standards on water disclosure that are consistent and aligned with international best practices, including Target 15 of the new Global Biodiversity Framework.

The ongoing journey towards internationally agreed standards for carbon disclosure is a major precedent. For instance, the International Sustainability Standards Board (ISSB) has highlighted the connection between the carbon and water agendas in its climate disclosure framework; it is also embarking on disclosure for biodiversity and ecosystems.

To date, two competing approaches to materiality co-exist. One aims at ecosystems restoration: the European Union (EU) Corporate Sustainability Reporting Directive (CSRD) defines as material both the impacts of a corporate on water resources and how water-related risks can financially impact that company. The other approach prioritises growth maximisation: only the financial impacts of risks are accounted for; typically, a corporate's impact or dependency on nature is only considered as material by the ISSB standard if it materialises through a specific cost. Whatever standard prevails, the overarching ambition should be to drive corporate behaviour towards a safe and just water future, considering both blue and green water.

Strengthening disclosure of corporate water footprints

Water is the main topic covered when countries carry out a natural-capital assessment. The next step is to raise companies' awareness of how their activity affects – and is vulnerable to – the hydrological cycle, so that their investments align with the ambition of water policies. This is a step towards corporations addressing their water dependency and the impacts of their supply chain on the hydrological cycle.

This task requires joint work among accounting professionals; experts in monitoring, review and verification; regulators and standard setters; institutional investors; and policymakers. Such an exercise will need a publicly available data platform and the institutional infrastructure to assess the stock, measure the flows, and value both the stock and flows coherently. Recognising water as an asset should not lead to hoarding and speculative behaviour.

Robust shadow pricing for water contributes to that objective, building on new data sources and analytical capacities. The recent initiative by Oxford University, Watermarq, the Asian Development Bank (ADB), WRC, and International Water Management Institute (IWMI) seeks to develop a novel, shadow water price framework to generate context-specific, differential shadow water prices based on indicators of resource availability and investment needs at the basin-scale.

Multilateral finance

Aligning multilateral, regional and national development banks

Multilateral development banks (MDBs) and regional development banks (RDBs), in collaboration with national public development banks (NDBs), have a comparative advantage in catalysing government and private sector investments. They bring together a package of knowledge, affordable financing, and risk-management to provide country-level support. They have a history of working with countries and stakeholders to enable private capital, and credit enhancements to cover public sector risk. Multilateral development banks can attract private sector investment by improving project design and structure, and lowering transaction costs, risk and risk perception, promoting policy and institutional reforms, and providing knowledge solutions (G20, 2016).

Multilateral development banks, regional development banks, and national public development banks can align their efforts around shared regional or national water challenges. To channel public development finance strategically, country platforms can be used to pool, structure, and direct finance towards national and regional water objectives. While countries will own the process, public banks will be crucial to help embed conditionalities so that the efforts of private-sector recipients contribute to those national or regional objectives.

The multilateral-development-bank system can be strengthened in two ways to support investments needed in the water sector. First, multilateral development banks should shift their operating model away from individual projects towards a country platform approach, where national governments take a lead in identifying multi-year transformations. Factoring in blue and green water can bring consistency across sectoral focuses. A programmatic approach combines procedural and substantive justice (Gupta et al., 2023; Gupta et al., 2024); it should help address socio-spatial inequality that otherwise can be exacerbated by water finance. Strategic planning can better align finance with national water and development priorities, and improve outcomes and benefits for communities.

Second, multilateral development banks should make engagement with the private sector core to their operations. A whole-of-MDB approach is required to co-create investment opportunities with the private sector, develop project pipelines, and mobilise and catalyse much higher volumes of private finance, in line with the conditions for mission-centred finance characterised above. This should be combined with a just allocation of risks and rewards between public and private financiers.

Considering debt-for-water swaps

First introduced in the 1980s (Essers et al., 2021), debt swaps are a partnership-based financial tool that aims to reduce sovereign debt burdens while promoting long-term sustainability (Sing & Widge, 2021). Debt swaps are applied primarily in middle-income countries with high but manageable debt. For countries under severe debt distress, traditional debt restructuring is generally preferable (Chamon et al., 2022).

The new generation of debt swaps frequently involves a buy-back of debt trading favourably on secondary markets, which is reissued under more favourable terms through a de-risked bond linked to environmental performance. A "haircut", reduced interest rates, and prolonged repayment periods provide partial debt relief and expand the fiscal space of a country, while part of the savings is directed to domestic environmental objectives (Roundtable on Financing Water, 2023).

Since 2020, a new generation of debt-for-nature and debt-for-climate swaps is emerging, restructuring an unprecedented amount of debt, as exemplified by swaps in Ecuador (USD 1.6 billion) (Nedopil et al., 2024), Barbados (USD 295 million),[53] and Belize (USD 553 million).[54] The debt-for-nature swap in Belize reduced the country's external debt by 10% of GDP. This resulted in Belize moving from a country near default to substantially increasing its fiscal space and improving its credit rating while securing USD 4 million a year until 2041 for marine conservation (African Natural Resources Management and Investment Centre, 2022; Bala et al., 2022).

While debt swaps in the environment traditionally target nature and climate objectives (often benefitting the global hydrological cycle inadvertently), there is an opportunity to finance freshwater-related projects. Debt-for-water swaps can address prominent water financing challenges, such as the need for long timeframes, limited creditworthiness, and a lack of clear revenue streams (OECD, 2022a). Several swap deals have adopted a programmatic approach, funnelling the proceeds to a trust fund, which distributes finance to individual projects.

Significant caveats must be kept in mind, which can undermine efficiency and scalability. These include high transaction costs, the need to ensure that a swap yields substantive debt relief (Nedopil et al., 2024), and a general lack of high-quality water data to enable monitoring (OECD, 2022a). This emphasises the need for careful analysis and tailoring of any debt-for-water swap to the national context and fiscal profile.

Establishing Just Water Partnerships

National and local governments, basin agencies (or new institutional mechanisms to govern evaporation-sheds) would benefit from designing transition strategies that systematically consider blue and green water as drivers and conditions for sustainable development for the territories under their jurisdiction. Just Water Partnerships could be tasked to: (1) consider the new science and economics of blue and green water as a condition or pillar for just economic development; (2) design and implement a transition strategy that articulates the interests of all groups of beneficiaries, including communities whose voices have been often ignored; and (3) develop financing mechanisms to support implementation of the strategy.

In Just Water Partnerships, governing agencies and development finance institutions collaborate to build capacity and enact policies that unlock the right type of investment. By structuring investment opportunities to pool smaller projects for increased bankability, designing guarantees and co-investment arrangements to hedge against risks, and properly regulating the agreements facilitating these investments, Just Water Partnerships can attract finance that might otherwise not have been mobilised to finance water (GCEW, 2023a).

Countries can design Just Water Partnerships tailored to the needs of communities and water-dependent sectors, combining financial and institutional arrangements that serve their context. In the case of Kenya, existing Kenya Pooled Water Fund (KPWF) structures can be combined with other sources of financing to ensure development efforts are coordinated and aimed at specific gaps (Kazimbaya-Senkwe & Mutai, 2021). Innovative financing tools, like environmental impact bonds, can be designed to address the particularities of local and national water systems. They can be combined with other forms of public-value-oriented finance to create bundled investment structures that catalyse water financing.

Financing Just Water Partnerships should involve more active and bolder use of the menu of instruments available to catalyse private

53 Barbados Debt-for-Climate Swap to Be Backed by European Investment Bank - Bloomberg

54 Belize Debt Case Study (nature.org)

investments. These could include first-loss guarantees, concessional finance elements for lower-income countries, and co-investment arrangements to manage risks – bringing together national or local governments, multilateral or bilateral financing institutions, corporates, and philanthropies. Concessional parts of the financing package can increase technical capacity and absorb broader macroeconomic and programmatic risks, while enticing private investment in project finance. The reforms of multilateral development banks focused on global public goods (for instance the World Bank's Global Challenge Programs) can support this direction.

Preliminary discussions point to a tentative list of success factors for Just Water Partnerships:[55]

- Ensure ownership by stakeholders in the territory
- Recognise and factor in interdependencies across distant countries (through atmospheric moisture flows or virtual water trade)
- Whatever the geographical scale, embed a national dimension (to enhance agency)
- Adopt (and adapt) the Water System Justice approach characterised in this report
- Empower Indigenous voices and marginalised communities
- Factor in water for a dignified life (Chapter 4)
- Where appropriate, review subsidies that affect the hydrological cycle in the territory, and promote sustainable farming practices

Future work to identify principles that support the development of Just Water Partnerships in various jurisdictions would be appropriate.

55 The list reflects comments received at a dedicated session convened by Water Aid at the Stockholm World Water Week. The GCEW is grateful to WaterAid for its engagement and support.

8. The governance of water utilities

Key takeaways

The role of water service providers is to deliver on the core features of SDG6, namely access to safe water, improved sanitation and rainwater drainage. In addition, **water service providers can contribute to the five critical water missions set forth in this report. They must do so in accordance with the Water System Justice approach** defined in Chapter 4.

In the new context for water, characterised by a destabilised hydrological cycle, this requires a shift in perspective: from moving water away from cities through centralised, grey and piped infrastructures to a focus on improved service and environmental quality, resilience, and justice, through efficiency, reuse, catchment protection, and the combination of green and grey infrastructure.

This transition requires policies and institutions that are fit for purpose. **The preference of governing agencies, regulators, and financiers for central, piped infrastructure should give way to promoting a mix of on-site decentralised and centralised systems to enable universal coverage and service access**. Priority should be given to serving those left behind first; phased universal coverage can be considered as a second-best.

For a vast majority of the global population, the role of individual provision, community managed services, and informal markets should be acknowledged and factored in. Water utilities, public-service organisations, or other arrangements should be tasked with gradually supporting the transition towards services in line with health, environmental, and economic regulation.

The transition also requires that, where they exist, **mission-centred water utilities (public or private) be governed to contribute to public value**. Economic regulation can provide the appropriate incentives by defining performance criteria, reviewing development and investment plans, setting adequate tariff levels and structures, and ensuring revenues from water tariffs contribute to improved service provision.

Tariffs should signal the full social costs of water use, with customer-assistance programmes targeted at poor households. Thorough reviews of which costs should be covered by water bills contribute to an economically efficient and socially just contribution of revenues from user tariffs.

Contractual arrangements between organising entities and service providers – be they public or private – should drive operational performance, public value, and justice.

Cities must become water resilient through water-use efficiency, reuse, protection, and expansion of green and grey infrastructure. They must address the growth of untreated wastewater, severe water shortages and flooding, and climate-induced impacts on the urban water cycle. It is imperative to allocate water equitably and reduce urban water consumption through demand assessment, management, and monitoring to ensure that ecosystem health is prioritised along with public health.

Rural areas face different challenges. The cost of connecting users to water supply and sanitation services can be high, and the capacity of service providers to generate revenues can be low, affecting their ability to operate and maintain infrastructures. While centralised water infrastructures bring economies of scale, they require large capital expenditure and their extension to remote communities has often not been financially viable.

This context exacerbates inequities related to: (1) lack of access to water services; (2) concerns about sustainability where water services exist; and (3) issues related to informal settlements.

Challenges and opportunities related to the governance of water utilities

Utilities around the world provide safe water and improved sanitation to city dwellers and rural communities. Anecdotal evidence suggest that they combine:

- Corporatisation as a condition for a clear mandate and objectives; accounting structures autonomous from organising entities (usually local authorities); and ability to access and mobilise financial resources. To be clear, corporatisation is about the strategic and operational autonomy of the service provider, and has nothing to do with the public or private ownership.
- Corporate governance that acknowledges the demand of (served and unserved) populations; and provides accountability mechanisms with appropriate rewards and sanctions.
- Skilled labour across the organisation, from management to financial and technical functions, and customer relationships.
- A robust business model with the capacity for revenues to cover operation and maintenance costs, and part of capital expenditure to maintain existing assets, extend service provision, and adapt to shifting conditions.
- Understanding that long-term investment is necessary, with a focus on outcome-based performance measures.
- Economic regulation operating in the public's interest and sheltered from political interference, which:
    - Sets performance targets and incentives so that private investors see appropriate returns while customers are protected

from monopolistic pricing in the absence of competition.

    - Designs tariffs and procedures for regular adjustments to reflect costs (including inflation), and enable timely maintenance and reinvestment.

    - Reviews development and investment plans.

- Targeted subsidies to ensure affordability for the poor.

- Efficient and equitable demand-management models and just water allocation regimes, which provide users with the water supply they require, and discourage excessive use.

This model can be found in high-income and low-income countries, often in urban areas where costs of connecting dwellers to a central infrastructure are lower than in rural areas. Where in place, it has delivered massive benefits in terms of access, health and reduction in child mortality, and protection of water resources.

However, it is far from ubiquitous and faces several challenges. Moreover, despite significant efforts and recent progress, one-quarter of the global population does not have access to safely managed drinking water, and half the population does not have access to improved sanitation. Access is lagging the United Nations (UN) Sustainable Development Goal (SDG) 6 ambition in some world regions (especially sub-Saharan Africa), and rural communities are most affected.

Where people have access, there are concerns about the sustainability of the service. In most high- and low-income countries, renewal of infrastructures is slower than the life-expectancy of assets (OECD, 2020). The investment backlog affects the operational efficiency of service provision, and delaying investment can jeopardise the financing model of services. In another context, lack of maintenance leads to 40% of boreholes in Africa being broken.

Informal settlements face distinct issues. Lack of land tenure can be an obstacle to public investment in infrastructure and networks; access to piped water is also often tied to users' tenure. An important message is that we cannot solve one aspect of people's lives (water supply) while neglecting others (dignified housing). Dignity should guide and prioritise action towards securing access to water supply and sanitation services to all.

This situation triggers justice issues. In the absence of service provision, communities have access to water through private vendors (typically, water trucks) operating in fragmented and usually unregulated markets at the interface of local authorities and utilities. One question is whether their role should be acknowledged and encouraged, and if so, what the financing model should be: vendors qualify as private sector but are not attractive to the private-sector branch of development finance institutions.

Ultimately, most utilities need to evolve. Whittington et al. (forthcoming) characterise three phases in the development of urban water supply and sanitation services.

Cities typically move along a water development path from low- to high-quality service provision, with movement between phases facilitated by shifts in political, technical, and financial "disequilibria":[56]

- In **Phase 1**, water supply coverage increases but quality of service and efficiency of consumption and production stagnates, trapped by insufficient government transfers and low tariffs.
- In **Phase 2**, economic growth facilitates increased revenues, allowing for investments in service quality and increasing access to improved sanitation. Production efficiency improves, but consumption efficiency remains low due to weak price signals and poorly targeted subsidies, and environmental quality often degrades.
- In **Phase 3** – which remains aspirational for many cities – governments and citizens demand improved environmental and service quality. Investments are made to improve the resilience of supply, and subsidies are more carefully targeted toward the poor.

The challenges to achieving Phase 3 of urban water policy include revisions of tariff structures (e.g., existing increasing block tariffs) to improve financial sustainability, increased use of information to improve consumption efficiency, and asset management and investment planning that weigh the benefits and costs of new capital investments in the context of climate change.[57]

While enhancing the efficiency of utilities has multiple benefits, it alone does not provide sustainable access to all and transition to Phase 3. Water access by marginalised users is an important question related to water justice in cities. Increasing urbanisation, especially in cities of low-income countries, will exacerbate urban water equity and access concerns (Amankwaa et al., 2022). Further, while extension of networks to unserved communities can yield economies of scale, decentralised systems have value when organised as a public service. Regulating off-grid water distribution is a crucial part of governing urban water infrastructure.

New ways to provide water supply and sanitation services are required. They combine:

- Mission-centred water utilities (Chapter 5).
- A Water System Justice approach that emphasises (but is not limited to) serving those left behind first.
- New infrastructure design and organisation.
- Financing models that question which costs should be covered by the water bill, and which combine clear price signals with targeted social measures.
- A model to manage the transition.

Ragavan et al. (2024) argue that a shift to a graduated model of provisioning can be facilitated by regulation that does not disrupt ongoing business models or push service providers to subvert regulation. Light-handed regulation that reduces financial disincentives, prevents rent-seeking, while addressing oligopoly and informational asymmetry and promoting safe services could be a viable alternative. The Differentiated Schemes strategy in Colombia provides an example.

Notably, the status of the operator should not be overstated. The share of private operation of water services remains limited (below 10% globally) and trends are ambivalent. While private operation of water services gains traction in countries such as Brazil and China, re-municipalisation is trending in several OECD countries. Second, and most importantly, there are examples on how public and private models of operation work well. A major review by the World Bank suggests that the status of the operator might not be the factor that drives the performance of service provision.[58]

56 The text here quotes Whittington et al. (forthcoming)

57 The transition to Phase 3 demands addressing core challenges beyond the scope of this chapter, such as land-market distortions, limited institutional capacity, fiscal space, and serious upstream and downstream water conflicts.

58 See https://elibrary.worldbank.org/doi/abs/10.1596/978-0-8213-7956-1. In the same vein, discussions building on IIPP research considered that commercialisation, involving the operation of public utilities on a profit-oriented basis through levies and fees, may or may not work, but must be coupled with fit-for-purpose institutional tools.

Towards mission-centred water utilities

This section explores several solutions to address the issues outlined above. It is inspired by a mission-centred approach to economics and policy, and a framework to characterise water-related justice.

Mission-centred water utilities

Water service providers have their own mandate in relation to SDG 6: affordable universal supply of clean water, sanitation, and treatment of wastewater, addressing stormwater drainage. This remains paramount. In the context of this report, it is noteworthy that water utilities are key institutions to deliver on the five critical water missions discussed in Chapter 5:

1. **Launching a new revolution in food systems.** Water utilities play a role in the development of (peri-)urban agriculture through water allocation regimes and the capacity to offer reclaimed water, where appropriate.

2. **Conserving and restoring natural habitats.** Water utilities can limit pressure on water resources through efficiency gains and water-demand management. They can minimise pollution by complying with environmental standards for wastewater and rainwater collection and treatment. Utilities around the world invest in catchment protection to minimise treatment costs. This creates co-benefits in terms of biodiversity and land use. It can also contribute to other missions. Decisive drivers here are the acknowledgement of the value of ecosystems, and contracts with farmers.

3. **Establishing a circular water economy.** Significant opportunities emerge in relation to using reclaimed water for non-potable purposes, and recovering energy and valuable substances from wastewater streams. Instruments such as feed-in tariffs for energy generated in wastewater treatment plants are key to shaping such markets.

4. **Enabling a clean-energy world and an artificial intelligence (AI)-rich era** to be achieved with much lower water-intensity. Utilities can contribute to a low-carbon transition through energy efficiency and the capacity to recover heat and energy from wastewater streams. Lower water intensity can be achieved by making use of diverse sources of water (including rainwater and reclaimed water), and supplying water that is fit for purpose.

5. **Ensuring that no child die from unsafe water by 2030.** This requires thorough operation and maintenance of existing assets, and delivery of services that comply with health standards. It also requires the capacity to consider options beyond the prevailing model of piped, central infrastructure, combining innovative infrastructure, operation, and finance. Particular attention will be paid to slum dwellers and most-fragile populations.

These missions illustrate the new complexity that water utilities face if they want to deliver on their mandate, adjust to the new context, and contribute to stabilising the hydrological cycle.

Water System Justice at the heart of mission-centred water utilities

The framework for Water System Justice provides a consistent and comprehensive approach. Table 8.1 shows how features can be reflected in the governance of water utilities.

The overarching message is that utilities should focus on serving those left behind first. This requires innovative design, operation, and financing of service provision, possibly combining centralised and decentralised services, with formal and informal service providers, at multiple geographical scales. Shaping the water utility sector to deliver this ambition requires institutional capacities to embed public value in service provision, and to inform symbiotic partnerships across a range of actors.

TABLE 8.1: Water system justice applied to water service provision

Justice	Service provision should:	Link to 2030 Agenda
Recognition	Serve the poor first. Recognition justice emphasises the needs of the poor, marginalised, disabled, and homeless, ensuring affordability and accessibility.	“leaving no one behind”; “the furthest behind first”.
Epistemic	Use other knowledges. Epistemic justice acknowledges diverse social norms and water, sanitation and hygiene needs.[59]	“intercultural understanding”, “recognise all cultures”
Interspecies	Protect water ecosystems. Interspecies justice mandates sustainable water abstraction, compliant wastewater discharge, and ecosystem-based management to maintain ecological integrity.	Improve water quality: reduce pollution and treat waste water; increase recycling and safe reuse; protect/restore water ecosystems
Intergenerational	Anticipate future demands. Intergenerational justice addresses past and present water depletion impacts.	Protect the planet from degradation to support present and future needs
Intragenerational	Use targeted subsidies to ensure affordability, accounting for intersectional in equality. This ensures equitable rights, with the wealthy subsidising water services for the poor and sharing water between users to meet basic needs.	Provide accessible, available, and good-quality water on-premises; adequate, equitable sanitation and hygiene for all; commit to Human Rights for water and sanitation.
Procedural	Ensure accountability through access to information, decision-making, civic space, and courts.	Support and strengthen participation of local communities in improving water, sanitation, and hygiene services.
Substantive	Meet minimal needs within water boundaries. This covers both Just Minimum. Access to water, sanitation, and hygiene services, and Just Allocation.	Access to all.

Source: Schwartz K. et al. (preprint), *Water Utilities: Putting the Furthest Behind First Gupta et al. (2024).*

59 For instance, across sub-Saharan Africa, careful consideration of cultural preferences when designing water supply, sanitation and hygiene technologies, and the significance of integrating women into leadership positions within community water-management and sanitation programs were crucial to enhance sustainability and effectiveness (Tsekleves et al., 2022).

Policy shifts to move the needle on water utilities

This section outlines options to accelerate transition towards Phase 3 utilities that deliver on the five critical water missions described above.

Promote diverse modalities to serve the poorest populations and communities

Central, piped infrastructure has distinct advantages. It triggers economies of scale in densely populated environments. The resulting governance framework typically includes economic regulation, control of service provision, and accountability mechanisms designed to respond to the monopolistic characteristics of network infrastructure. It embodies a well-established business and financing model, where the public sector is usually charged with covering capital expenditure, while users are expected to cover operating expenditure. It has delivered robust services in both high-income and low-income environments, in line with Phases 1 and 2 of the development pathway presented above.

The model also faces limitations:

- It cannot provide access to billions of people globally, especially in rural/peri-urban/remote communities and informal settlements.
- It triggers high up-front costs, which require specific financing models.
- It faces challenges in transitioning towards Phase 3 of the development pathway and adjusting to shifts in demographics or climate.

In such contexts, urban and national policies and programmes should consider diverse arrangements (i.e., centralised and decentralised, networked and non-networked, formal and informal) and promote an appropriate combination at scale, adjusted to the urban context (Box 8.1).

Box 8.1: Acknowledging the comparative advantage of informal service providers

Informal service providers are increasingly recognised as critical to enabling universal access to water, sanitation, and hygiene services, especially in informal settlements. Evidence from several regions and countries suggests that informal service provision represents a sizeable share of the global market.

Around 25-70% of urban population the world over could be relying on informal providers (Arias-Granada et al., 2018; Asian Development Bank, 2024; D. Garrick et al., 2018). Besides the lack of formal services, inadequacy in the form of their poor quality or reliability drives demand towards off-grid alternatives. In certain cases, the inability of public utilities to keep pace with rapid growth and expansion in urban areas, along with large capital investment needed in networked infrastructure, has led informal service providers to be co-opted to meet requirements (D. Garrick et al., 2018; USAID Urban Wash, 2023).

While unit costs can be higher, decentralised systems can increase access and systemic resilience. Also, capital costs can be much lower, which matters in low-income countries where borrowing costs can be exorbitant and debt problems are pervasive. These solutions ought to be mainstreamed where appropriate. Decentralised systems can:

- Be scaled up and down to reflect population dynamics.
- Adapt to uncertainties about water availability triggered by climate change.
- Accommodate alternative financing mechanisms, including small-scale or even micro- finance.

Box 8.2: Decentralised on-site water reuse systems

San Francisco (California), United States, is leading the trend in "extreme decentralisation" of water reuse: making it mandatory for all new buildings with footprints larger than 100,000 square feet to include on-site water reuse systems. For example, the headquarters of the San Francisco Public Utilities Commission flushes its toilets with wastewater treated in engineered wetlands built into sidewalks around the building. This process reduces the building's imported potable water supply by 40%.

In Bengaluru, India, some apartment complexes treat their wastewater and use it for laundry and washing. One complex supplies treated potable water to industry, both reusing water and earning revenue.

A study in South Africa indicated that, for population densities below 112 persons/hectare, simplified sewerage was more expensive than onsite sanitation options, which could be due to higher costs associated with pumping-station maintenance and monthly household surcharge. However, for densities above 198 persons/hectare, sewerage became cheaper than onsite sanitation options at the same costs (Manga et al., 2020).

In the Char communities of Bangladesh, with fluctuating heavy rainfall patterns and a history of migration, constructing temporary, low-cost structures that can be easily rebuilt has been common, as opposed to costly permanent structures that might be abandoned or damaged (Mills et al., 2020).

Decentralised systems also face limitations, such as lack of technical and financing capacities, and more challenging monitoring of performance and compliance with existing regulations. Modalities to monitor and enforce compliance with environmental and economic regulation need to adjust to such contexts. This can be done via utilities or a public service organisation (Box 8.3).

While allowing for small-scale operational units, aggregation of small service providers can improve operational performance and sustain technical and financial capabilities.[60] It can also provide opportunities to comply with environmental requirements in a cost-effective way. Several aggregation options can be considered, from shared functions to merging.

Box 8.3: Decentralised public sanitation services in France

A SPANC (service public d'assainissement non collectif) is a public service company with responsibilities related to equipment, maintenance, and functioning of non-connected wastewater treatment systems. These sanitation facilities collect, transport, treat, and dispose of all domestic wastewater (except rainwater) from buildings not connected to a public network. SPANC shows how the development of a non-fixed network provides an effective alternative to wastewater network provision in sparsely populated areas, while offering environmental protection (Chapter 5).

Transitioning can require letting different standards co-exist for a set transition period. While this might not be in line with the just water system approach, such strategies can be practical ways to transition towards better service for all, as illustrated by Colombia's Differentiated Schemes strategy (Chapter 5).

Embed public value in the governance and review of water utilities

Public value as a concept for water utilities should come with metrics to report and measure success. Typically, this calls for utilities to maximise social welfare, i.e., social-cost/-benefit analysis should guide utility investment and policy decisions. Framing questions can help operationalise the notion:

60 For practical considerations on the pros and the modalities of agglomeration, see OECD (2022).

- Who are utilities willing to serve?

- Who oversees servicing the poorest parts of the population: a water utility (through a dedicated pro-poor unit), local authorities, or someone else?

- What are the success factors in relation to Water System Justice?

Answers are likely to be country-specific, but some generic framing might be relevant. Options to make publicly or privately operated water utilities mission-centred and urge them to maximise public value include:

- Hold service providers and organising authorities accountable for performance, combining social, environmental, and economic criteria.

- Promote corporate governance arrangements that keep citizens informed and involved, and hold decisionmakers accountable for service delivery.

- Corporatise service provision as a condition to keep political interference at bay. Independent of the status of the operator, corporatisation has advantages in defining, driving (through rewards and sanctions), and monitoring performance. It is a condition for financial integrity and transparency. Corporatisation can apply to decentralised systems, as illustrated by SPANC in France.

- Consider employment and professional training as an opportunity to turn staff into custodians of public value. Skill partnerships can be relevant.

Reporting has a role to play, like corporate social responsibility for financial institutions. New metrics are required to quantify access and justice. There would be benefits in characterising the role of independent economic regulation to define, promote, and realise public value in practice.

Contracts, partnerships, and regulation

Contracts and partnerships

Contracts organise the relationships between the organising entity (usually a local or regional government) and the service provider (be it public or private; again, this discussion is agnostic as regards the status of the service provider). Where they exist, contractual arrangements do not likely reflect a multidimensional perspective on performance, nor provide adequate incentives. There is room to design and enforce contractual arrangements that drive operational performance, public value, and justice.

Conditionalities are effective in steering the operation of water utilities towards public value by setting balanced incentives and risk-sharing. Governments can embed conditionalities in contracts to (Mazzucato & Rodrik, 2023; Mazzucato & Zaqout, 2024):

- **Prioritise those most in need**, such as slum dwellers, the most fragile populations, and women and girls (considering prevailing gender inequality in access).

- **Improve water conservation and the efficiency of water use**, urging water utilities to curb water-demand management through fixing pipes, and chasing non-revenue water. To mitigate impacts on revenues, additional sources of income disconnected from the water bill could be explored to cover the fixed cost of service operation.

- **Reinvest revenues in productive activities**, such as R&D and innovation around water, to promote cost-effective and low-carbon modes of operation, or digitalisation (e.g., digital twins) to support performance improvement.

- **Reinvest some revenues into catchment conservation programmes.**

Partnerships supported by conditionalities can be defined to ensure that water utilities are governed to deliver in line with the expectations of national or local authorities. Performance-based contracts for water services illustrate that kind of arrangement.[61] Economic regulators have a role in setting performance standards, monitoring and reporting on achievements, and providing incentives and sanctions.

Fair and effective partnerships require that the public sector have capacities. More work is required to characterise such capacities and develop the appropriate curricula and training opportunities.

Regulation[62]

In principle, three sets of regulations apply to water utilities. First, health regulations set standards for potable water and service quality. Second, environmental regulations are designed to safeguard water resources (quality and quality) and enable reuse. The primary focus is on water abstraction and discharges. Ragavan et al. (2024) documents the interface between the urban water cycle and the water cycle at large. It emphasises the benefits of rainwater harvesting and groundwater recharge. These can only materialise if the protection of surface and groundwater is properly regulated. Third, technical regulations are designed to ensure efficiency in water use; they can also promote energy efficiency and lower carbon footprints.

From an economic and social perspective, national regulatory authorities supervise the provision of essential services by monopoly suppliers. They aim to enhance the cost-efficiency of utilities, foster investment, and protect customers from poor-quality services and unjustified tariff increases. Economic regulators review tariffs to identify the amount of revenue that adequately covers the cost incurred by a regulated entity while incentivising efficiency in service development, investment, and operation. Best practices stimulate efficiency and discourage overinvestment.[63]

Contract design can improve cost-efficiency in service delivery. Critically, a service provider knows more than its regulator about their own cost structure and level of efficiency. This informational asymmetry translates into a bargaining advantage that can lead to inadequate services, inflated costs, or the ad hoc renegotiation of contracts. These inefficiencies translate into higher rents or returns for the service provider. With appropriate attention to contract design, many of these problems can be mitigated. Capping the price of the service can be a good option, and requires minimal access to cost data. In other contexts, a more appropriate contract would limit the allowable rate of return by defining a maximum markup over audited costs ("cost-plus"), complemented with international cost benchmarking. Offering a menu of choices can be a good option: in expressing a preference, firms reveal information about their cost structures and comparative advantages, which allows for better-informed regulation.

However, prevailing models of economic regulation for water service provision have not always ensured delivery of service for public value. Anecdotal evidence suggests that revenues are not adequately pumped back into the maintenance of water and sanitation treatment systems, leading to lack of investment, infrastructure decay, and degraded service quality. Lessons can be learned from recent successes and failures about the ambition and modalities of economic regulation for water services.

Typically, while national regulatory authorities cover several aspects of a firm's policy (cost efficiency, investments, quality of services, customer care), other aspects, such as corporate financing policy, remain neglected. The example of England and Wales suggests that leaving out corporate finance led to a higher risk of ineffective financial structure, oriented toward short-term profit maximisation and dividend payouts. Experience shows the strong preference of water utilities for debt maximisation, achieving a debt-to-equity ratio beyond the notional value established by the economic regulator.

Where water utilities' balance sheets have debt, national regulatory authorities could intervene to reduce risks from over-indebtedness that reduces the availability of finance for investment,

61 See synthesis by the International Water Association; https://iwa-network.org/groups/performance-based-for-improving-utility-efficiency/

62 This section is based on a personal communication from the President of the Association of European Regulators in the drinking water and wastewater sector (WAREG).

63 For a detailed analysis of the tariff methodologies adopted by European national regulatory authorities, see the Association of European Regulators in the drinking water and wastewater sector (WAREG) report: https://www.wareg.org/documents/water-tariffs-frameworks-in-europe/.

damaging the quality of services. A range of actions could avoid such situations, including corporate governance or regulatory levers. Considering their mandate, water utilities should have governance and capital structures that impede corporate management from adopting strategies that result in ineffective performance. More work is required to characterise such developments in regulation and governance.

Tariffs for water supply and sanitation services

Trying to achieve several policy objectives using tariffs has proven ineffective: it has often undermined operational performance and deterred investment, with socially unjust consequences. Tariffs are best conceived in conjunction with targeted social support outside of water bills.

Each of the three phases of urban water development characterised above face challenges when it comes to pricing and associated subsidies:

1. In Phase 1, subsidies to connection and operation can be poorly targeted: cheap tariffs do not benefit the poorest households, who are not connected.

2. In Phase 2, a pressing issue is how to set tariffs to raise revenues and ensure that poor households can still afford water, while enhancing the operational efficiency of the service provider. Increasing block tariffs have been the answer in many cities in the Global South, but they often fail to deliver and can be socially regressive.

3. In Phase 3, regulators signal the full social costs of water use; customer assistance programmes target subsidies to poor households who need them. Singapore's U-Save subsidy programme illustrates one way this can be done without compromising the incentives customers face to use water wisely (Box 8.5).

Box 8.5: Leveraging tariffs and subsidies for public value

Subsidising connections in Africa

In Nyeri, Kenya; Kampala, Uganda; and Dakar, Senegal, subsidised connection charges enabled coverage to more than double within a decade. In cities such as Maputo, Mozambique; and Mzuzu, Malawi, informal supply modes such as standpipes and water kiosks are also subsidised (Beard & Mitlin, 2021).

Block tariff structures coupled with targeted subsidies in Singapore

Singapore uses a block tariff system for households, coupled with targeted subsidies for lower- and middle-income households. The large first tariff block includes a water conservation tax and enables the long-term cost of producing and distributing water to be recovered. While 96% of households fall into this first block, a significant proportion of them receive a targeted and progressive rebate to ensure affordability. The U-Save subsidy programme delivers quarterly rebates to poor and middle-class households who live in public housing, to help them pay utility bills (water, gas, and electricity). The size of the rebate depends on the size of the housing unit; households who live in lower-value housing units receive larger rebates.

First, costs can be minimised when economic regulation provides incentives for operational performance and for economic efficiency of development and investment plans. In practice, reliable, safe, and sustained service delivery benefits from investment decisions that factor in realistic assessments of lifecycle and long-term service costs, along with the professionalisation of service delivery (Garrick et al., 2020). An important caveat is that information on (true) costs is private and unknowable to the regulator. In the absence of competition, it is challenging for regulators to find the appropriate level of pressure (see above).

Cost can also be minimised through alternative infrastructure design or agglomeration of small service providers. The cost of capital matters as well in a capital-intensive industry such as water supply and sanitation. Patient and local capital has a role to play; paying back high-interest loans in foreign currency is prohibitive.

Second, one needs to specify which costs should be covered by the water bill. International experience suggests there is room to implement the polluter pays principle more systematically. For instance, in the context of revising the Urban Wastewater Treatment Directive, the European Commission is setting up an extended producers' responsibility mechanism so that pharmaceutical and cosmetic industries cover the costs of additional treatment required to control pollution from the substances they market. Such a mechanism can inspire regulators in other parts of the world, including in the Global South, where a significant part of the costs incurred by water users results from harmful practices upstream.

Third, tariffs for water supply and sanitation services are best designed to signal the full social, environmental, and financial costs of service provision, including the scarcity of freshwater. They would apply to all water users. Poor households would be compensated through targeted social support outside of the water bill. Such a principle conveys the right message to water users in a simple and transparent way. And it makes the most effective use of public funding.

Tariffs can be combined with policy instruments such as abstraction charges or nudging to signal the opportunity cost of using water, especially when the resource is scarce. Demand-side approaches to improving and sustaining water, sanitation, and hygiene outcomes need innovative and targeted behaviour-change communication and strategies (Chirgwin et al., 2021).

Finally, it should be acknowledged that not all parts of the water value chain are equally able to attract finance or generate revenue. It might be difficult to generate revenue to provide access to unserved areas, be they poor neighbourhoods, remote communities, or informal settlements. Some cross-subsidisation along the water continuum and the multiple duties of water utilities can be justified when sanitation is not affordable. National and local governments should be encouraged to consider which subsidy is most appropriate to cover the cost of service-provision where no revenue can be generated. The answer will be specific to each jurisdiction.

When in place, tariffs for water supply and sanitation services should be adjusted to reflect costs and enable timely maintenance and reinvestment. Lack of adjustments can explain why utilities find themselves trapped in Phase 2 (or even regressing from Phase 3). Economic regulation is key to ensure that tariff adjustments are justified and do not undermine incentives for operational efficiency.

The question remains about how much revenue collected through tariffs should and could finance massive investments required to keep up with local and global ambitions and adapt water services to the new context characterised in this report, such as to deliver climate-resilient infrastructure, replacing today's aging assets. How should tariffs consider this long-term perspective, which raises issues of intergenerational justice? To what extent should current customers pay to benefit future customers?.[64]

Additional revenue streams

In addition to tariffs, diverse financing mechanisms can be explored to generate the cashflows required to finance water supply and sanitation services. Three options are recommended:

- **Extended producer-responsibility mechanisms**, as described previously, can serve to comply with the polluter pays principle. Where appropriate, they generate revenues that can be earmarked to finance treatment of water before it is supplied to users. Their justification and design require robust investigations of the source and costs of pollution.

- **Capturing the value of private benefits triggered by public investment** in infrastructure makes economic sense and is socially just. Land-value capture can generate fiscal space for (national or local) governments[65] and contribute to financing water-related investments, where

64 For recent behavioural experiments to reveal preferences of consumers, see page 70 of https://www.oecd.org/gov/regulatory-policy/scotland-s-approach-to-regulating-water-charges-fcc8c6df-en.htm.

65 See an exploration of land-value capture to finance flood protection in Indonesia: OECD (2023). Similar reasoning can apply to water supply and sanitation.

investments in water supply and sanitation generate private benefits for landowners and property developers.

- **Wastewater treatment can generate valuable materials** and contribute to a circular economy. With only 39-76% of the total energy used in anaerobic digestion processes reclaimed, there is scope to tap into the energy generation of domestic wastewater, which can be up to ten times the energy required for its treatment (Barroso Soares, 2017). Technologies are available to collect heat, methane, or substances that have economic value. Adequate regulation (e.g., feed-in tariffs for energy supply) can incentivise recovery, generating revenues for utilities that are independent from the volume of water sold or treated. The financial relevance of such schemes depends on the market price of recovered materials, which can vary, affecting the business case for such developments.

9. Harnessing data as a foundation for action

Key takeaways

Data is critical for transforming how we govern water at every scale from local to global and across sectors, to achieve the 3Es: efficiency, equity and environmental sustainability. However, **the data landscape today has many gaps and is highly fragmented**, particularly regarding green water.

We should work towards a global water data infrastructure to enable science-based decision making, recognising and building on data at every level of the hydrological cycle including local and Indigenous knowledge, and empowering all stakeholders including citizens to shape decisions on water. To achieve this, we must strengthen data collection from the local level up, and aim for interoperability of data reporting by promoting harmonisation with recognised measurement and reporting frameworks.

We should generate momentum for corporate water footprint data disclosure through actions by coalitions involving the private sector and civil society organisations. We should expedite work on regulatory standards to mandate water disclosure. Such requirements should aim to provide transparency on the double materiality of water risks posed by companies' operations – including both their own vulnerabilities to water stresses and disruptions, and the impact of their operations on water resources and land-use changes. **We also recommend that water disclosure be integrated** in carbon transition plans and be an integral part of sustainability-related disclosures.

Crucially, we must develop pathways to value both blue and green water as natural capital. Though still in its early stages, this initiative is an important enabler for responsible stewardship of freshwater ecosystems, enabling governments and all stakeholders to evaluate the costs and benefits associated with land conversions, conservation, and restoration projects.

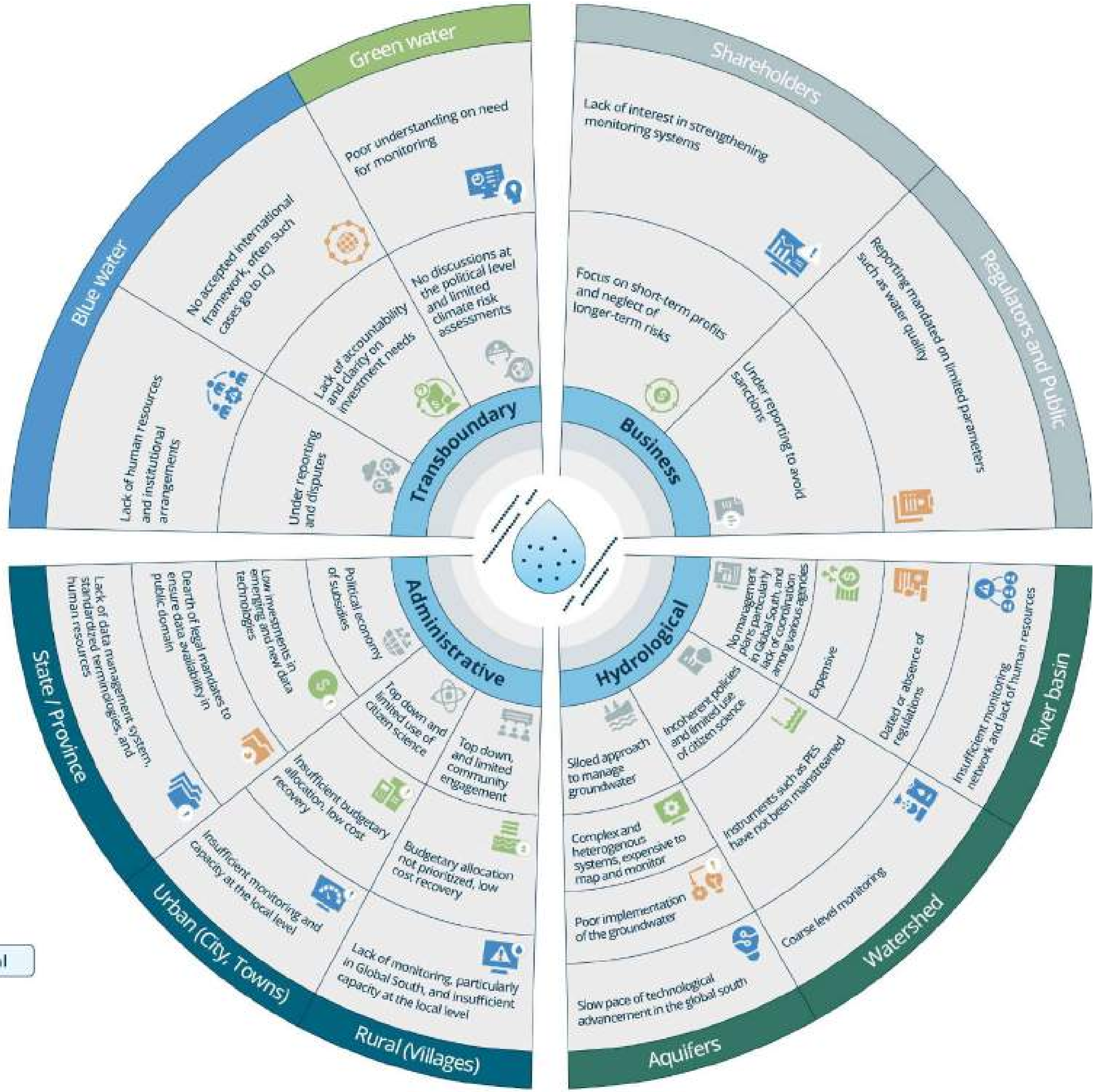
Data underpins transformations in how we value and govern water necessary for the missions outlined in Chapter 5 to succeed. However, large gaps exist and, alarmingly, water data collection and quality have been decreasing in recent years. The data landscape is highly fragmented, reflecting a lack of institutional capacity and citizen engagement, insufficient funding, siloed management approaches, and a reluctance to share data publicly (Figure 9.1). Gaps exist at most hydrological and administrative scales, reflected in data repositories compiled under the United Nations (UN) Sustainable Development Goal (SDG) indicators, as well as other policy frameworks and conventions. This holds true for both blue and green water, with especially green water data largely overlooked.

FIGURE 9.1: Why is water data missing?

Why is water data missing?

Challenges

Technical | Financial | Legal | Political



Unlocking the potential of data

To unlock water action, we must embark on a systematic effort to collect data that is comprehensive, of high quality, timely, interoperable, and publicly accessible (Figure 9.2).

Governments need data covering the full hydrological cycle for sustainable water governance. This includes river basin,[66] inter-basin, and inter-sectoral water management, understanding land use change and forest-water interactions, and ensuring water-use efficiency, water quality and sustainable use of groundwater. Water data also support comprehensive tracking and evaluation of investments in water and implementation of policies at different geographical scales. At the local level, behavioural, preference and socioeconomic data can complement water data to inform justice assessments and guide context-specific policy. For example, field research in Tajikistan helped visualise that providing training directly to women increased participation in community-managed water-user associations (Balasubramanya, 2019).

Box 9.1 – Water Accounts: State of Play and Ways Forward

The System of Environmental-Economic Accounting (SEEA) provides a comprehensive and systematic framework to understand the interactions between the economy and the environment. The SEEA-Water framework focusses exclusively on water resources and details the ways in which the economy uses water, including physical flows and stocks, and economic parameters (UN, 2012). It is noteworthy that the framework does not consider green water.

Water accounts provide policymakers with key information to support integrated water resources management (IWRM). They also contribute to a suite of indicators commonly used for monitoring and reporting of green growth and sustainable development. Due to these reasons, water accounts were selected as one of the five priority accounts (in 2016) for establishing global databases by the UN Committee of Experts on Environmental-Economic Accounting (UNCEEA).

The OECD has been tasked to lead the development work on water accounts. However, given countries' limited adoption of water accounts, new avenues need to be explored to facilitate their compilation at national level. Recommended areas of work include:

- *Stocktake countries that compile water accounts, their methods, and the key policy applications.*
- *Review the availability of global datasets (including from Earth observation, model-based research datasets, and corporate data) and analyse their suitability for gap-filling in official water statistics and water accounts, considering both blue and green water.*
- *Develop recommendations for international efforts to enhance the quality and availability of water statistics and accounts globally, such as by exploring the bridges between water statistics, water accounts, and the place of water in ecosystem accounts.*
- *Develop use cases on how improved official water accounts and statistics can support countries' national and international objectives and strengthen countries' capacity to manage water resources sustainably.*
- *Build a harmonised global database on official or nationally validated water accounts and statistics.*
- *Rally support and engagement from a range of stakeholders towards further enhancement of water data, statistics, and accounts globally.*

Work along these lines is a clear case for the benefit of international cooperation.

66 The European Union (EU) Water Framework Directive (WFD) (Directive 2000/60/EC) is an example of how data facilitates river basin management.

Firms can use data about the impact and dependency of business activities on water resources to mitigate water and climate risks in supply chains and operations. They can also steer investment and consumer preferences towards sustainable and just practices, including water conservation. Recent regulatory developments such as the European Union (EU) Corporate Sustainability Reporting Directive (CSRD), underscore the importance of robust corporate water-related data.

Comprehensive water data is crucial for citizens' informed participation in water governance and management. Access to water data enables communities to understand local water resources, quality issues, and risks, fostering engagement in water-related decision-making and development of locally relevant solutions. By democratising access to water data and providing tools for its interpretation, citizens – including youth and Indigenous Peoples – are empowered to play a role in water conservation, pollution monitoring, and sustainable water-use practices. Granular data, covering informal and formal water services, is critical for visualising local inequalities in access to water and sanitation, and allowing stakeholders to design more just allocation and water services (Balakrishnan & Anand, 2015). Democratising water data will require local capacity for data collection and analysis, including intercultural approaches (Mehltretter, et al., 2023), by providing funding, technical support, and training to local institutions and communities.

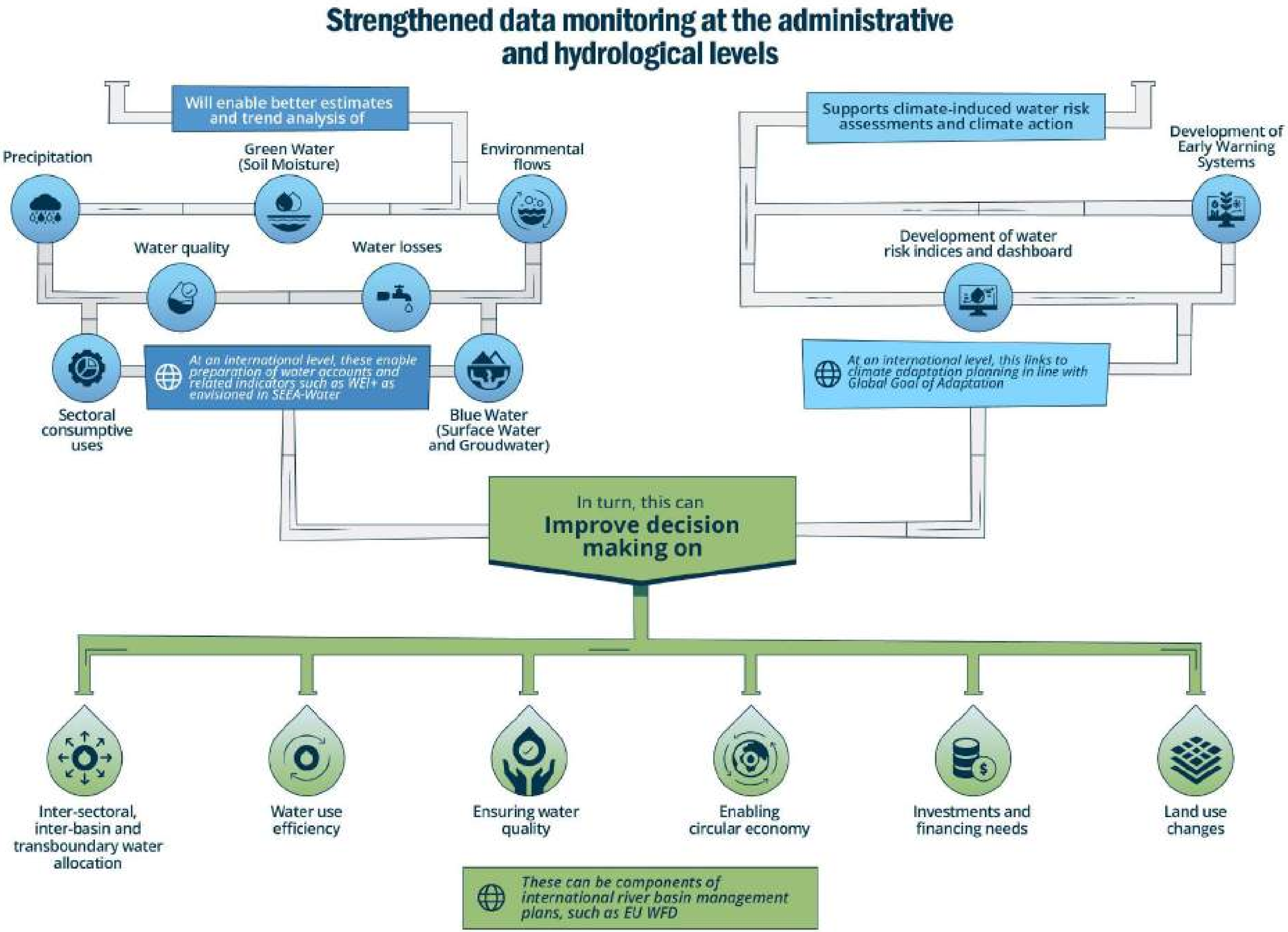
As also indicated in Chapter 7, a long-term goal must be to enable water to be valued as part of natural capital. Recognising and evaluating the services freshwater ecosystems provide for well-being, economic growth, and sustainability encourages investment in their protection. By the evaluation of costs and benefits associated with land conversions, conservation, and restoration projects, it also helps governments and stakeholders make decisions about land use (Annex 9.1, Box 2). The valuation of water-related ecosystem services can expand the use of debt-for-water swaps, allowing countries to reduce their sovereign debt burdens. The data would help structure swap agreements based on measurable water conservation outcomes, ensuring that investments lead to tangible environmental and economic benefits.

Recommended pathways for action

First, we should work towards a Global Water Data Infrastructure that empowers stakeholders with access to blue and green water data for science-based decision-making through an integrated data platform, recognising and building on data at every level of the hydrological cycle including other knowledge systems (such as local, religious, rural, traditional, and Indigenous knowledge). To ensure epistemic justice, the infrastructure can provide a platform for co-developing a process to identify how to aptly integrate different knowledge systems alongside behavioural, cultural, and ecological data. Governments should curate and manage this digital public infrastructure to support the efficient, equitable, and environmentally sustainable governance of the hydrological cycle in the public interest (Eaves et al., 2024). The infrastructure should facilitate the aggregation, harmonisation and utilisation of existing hydrological data (Annex 9.1, Box 2) and the development and verification of new data and generation capabilities. To improve data interoperability, and enabling comparative analysis and benchmarking, promoting harmonisation with internationally recognised measurement and reporting frameworks such as SEEA-Water constitutes a key objective of the infrastructure. It is important to note that incentives and disincentives play a role in data quality and might cause misreporting.

Data collection would primarily occur at sub-national and national levels, led by governments and local stakeholders in the interest of nations and communities. It is essential that this data can be aggregated at every hydrological scale and be interoperable by aligning with internationally recognised concepts and methods. It is recommended to establish a country-level foundational water data package, which would serve as a guideline for data contributions and reporting on SDG 6 and beyond. Notwithstanding, nations and communities should have some level of data sovereignty, and reporting needs to be sensitive to existing circumstances, priorities and capabilities.

FIGURE 9.2: Strengthened data monitoring at the administrative and hydrological levels



Box 9.2 - The Global Water Data Portal

The Global Water Data Portal is a key component of the Water and Climate Coalition (WCC) that supports the implementation of the UN Decade of Action through the UN-Water SDG 6 Global Accelerator Framework (GAF). The Portal aims to provide unified access to relevant water data sources and aggregate relevant water data to support the fulfilment of the SDGs and improve policy development, national and regional adaptation actions, and efficiency in water monitoring and management. It will link existing water information systems like the Food and Agriculture Organisation's (FAO) AQUASTAT and WaPOR, and World Meterological Organisation's (WMO) Global Hydrological Status and Outlook System (HydroSOS), providing geospatially referenced information that enhances data visualisation and decision-making capabilities.

Second, we must strengthen capacities and financial support to collect data and aim for interoperability of data-reporting within water basins and globally. As atmospheric moisture-tracking and global hydrological models rely on harmonised datasets of climate variables, improving these models' underlying data is critical. New technologies, such as low-cost satellite monitoring, are enablers that could capture parameters beyond blue water, including soil moisture and the state of the hydrological cycle. For instance, the Trishna mission will advance the measurement of evapotranspiration as of 2027.[67]

Multilateral organisations and stakeholder coalitions should urgently collaborate with national and local authorities to build data collection and harmonisation capabilities and systems, including operation of new technologies. Expanding the capacity of real-time monitoring is also essential. As explained in Chapter 5, real-time monitoring of groundwater levels can inform abstraction rates, supporting sustainable use of groundwater. Incentivising local governments and communities to mobilise data in decision-making processes is also important to ensure that data is translated into effective policies. Citizen engagement in monitoring and data gathering can complement public and private efforts while supporting data democratisation and justice. Community-based monitoring offers opportunities for more efficient, affordable, and scalable approaches. The Institute of Public and Environmental Affairs (IPE)'s Blue Map app is one example: with 3.8 million users, the app leverages citizen science to monitor and report on environmental data in China, enhancing transparency and accountability.

Third, we should generate momentum for market-based disclosure of corporate water footprints through actions by coalitions involving the private sector and civil society organisations (Annex 9.1 Box 1). This can build on tools such as the World Wide Fund for Nature (WWF) Water Risk Filter.[68] CDP – a not-for-profit that runs a global disclosure system for investors, companies, cities, states, and regions to manage their environmental impacts – is also active in this, having collected water security data from nearly 4,000 companies globally since 2009, with the aim to expand collection of relevant water-related data from 90% of the world's highest-impact companies by 2025. The Treaty on Transnational Corporations and Human Rights being negotiated under the UN Human Rights Council could accelerate this effort.

Fourth, we should work towards regulatory standards on water disclosure that are consistent and aligned with international best practices, including Target 15 of the new Global Biodiversity Framework. These standards should inform data collection regimes enabling disclosure of double materiality of water risks posed by companies' operations – including both their own dependencies and supply chain risks, and impact of their operations on water resources and on the hydrological cycle,

67 The Thermal infraRed Imaging Satellite for High-resolution Natural resource Assessment mission is a partnership between the French and Indian Space Research Agencies to observe the temperature of the Earth's surface. This provides information to determine the water stress of plants and their evapotranspiration. https://cnes.fr/projets/trishna

68 The WWF Water Risk Filter allows companies to assess three types of water-related business risk: physical, regulatory, and reputational. Companies can explore maps of water-related risks, now and by 2030-50. As a screening and prioritisation tool, the Filter helps identify water risk hotspots across multiple sites, and focus on what and where it matters to mitigate water risk to enhance business resilience. WFF, 2023).

including through land-use change. It should also recognise the interconnection between the conservation of blue and green water, and net reduction in carbon emissions. The International Sustainability Standards Board (ISSB) is advancing global sustainability-related financial disclosure standards for capital markets, building on the Task Force on Climate-related Financial Disclosures (TCFD) recommendations. It is expanding its work beyond carbon to biodiversity disclosure (see also Chapter 7). We recommend that water disclosure be integrated in carbon transition plans and be an integral part of sustainability-related disclosures.

Fifth, we must value water as natural capital. This effort is in its early stages, with much work ahead. It is an important enabler for responsible stewardship of freshwater ecosystems, and decision-making on land-use changes. Efforts begin at watershed-level with natural capital assessments to demonstrate a clear link between investments to preserve or restore a watershed and downstream benefits for users (Annex Box 2). Valuing these ecosystem benefits forms a basis for agreements between local communities, governing authorities, and the private sector on the use of a watershed. Work on frameworks and tools to document and incorporate natural capital in decision-making is ongoing under coalitions such as the Alliance for Water Stewardship,[69] , the Capitals Coalition,[70] and the collaborative initiative between the UN Environment Programme World Conservation Monitoring Centre (UNEP-WCMC) and other stakeholders on a Toolkit for Ecosystem Service Site-Based Assessment (TESSA)[71] (UNEP-WCMC, 2022). We can build on open-source tools such as InVEST, which combines data gleaned from thousands of researchers working with techniques like satellite imaging, soil surveys, climate modelling, and human development mapping, to quantify and place a value on natural resources. Also, the concept of a Gross Ecosystem Product (GEP), approved by the UN Statistical Committee in 2021, has been adopted in China to measure the aggregate monetary value of ecosystem related goods and services in specific regions (see Annex 9.1 Box 2).

UN Statistical Committee in 2021, has been adopted in China to measure the aggregate monetary value of ecosystem related goods and services in specific regions (see Annex 9.1 Box 2).

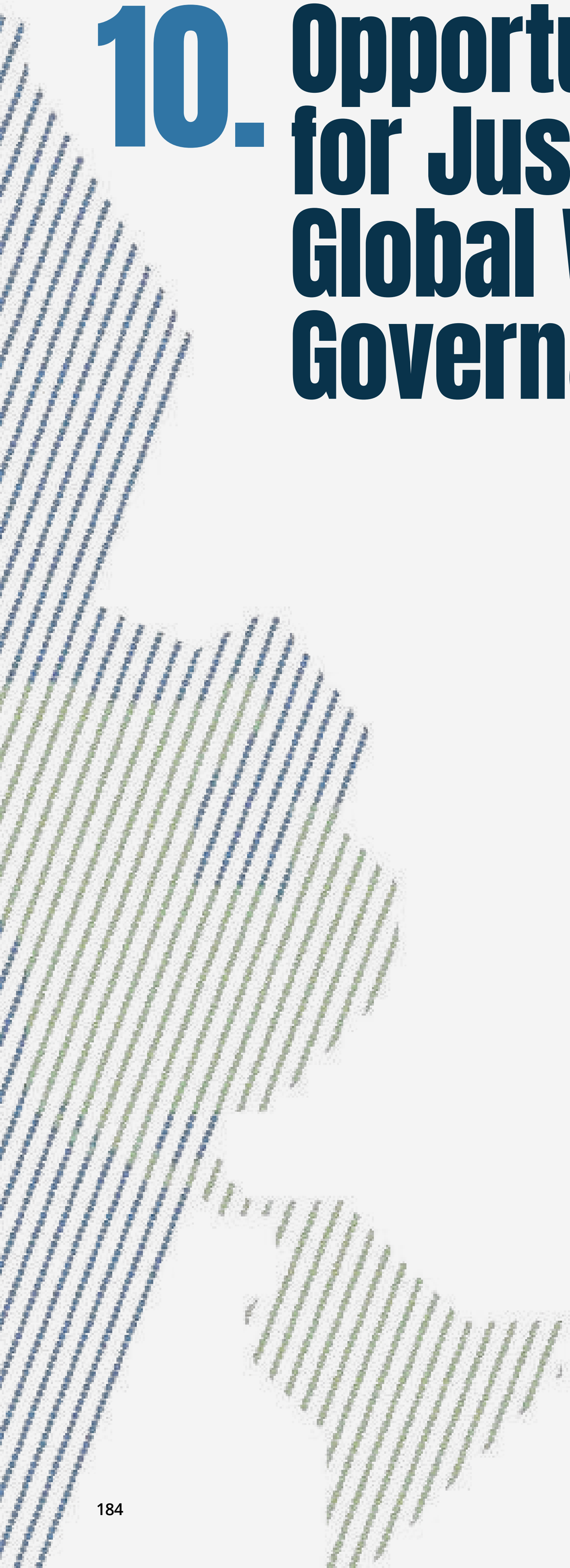
Sixth, attention has to be paid to ensuring equity, in areas such as the creation of data that might otherwise remain unrecognized, and in in ownership and access to data. The marginalised should not be disadvantaged by the absence of (access to) data about the challenges they face.

69 The AWS Standard 2.0. Alliance for Water Stewardship (2020).

70 Natural Capital Protocol (2016)

71 The value of freshwater ecosystems and the benefits from their restoration (link). UNEP-WCMC (2022).

10. Opportunities for Just Global Water Governance



Key takeaways

Acknowledging and promoting the hydrological cycle as a global common good requires just water governance that acknowledges global-local linkages and serves a multi-scale framework for action.

Water should be considered as an organising principle to successfully implement sustainable development. We must adopt a "water and beyond" perspective across all agendas and domains.

The international community must construct a fit-for-purpose governance architecture that facilitates collective and mission-centred action on water, and accounts for the major legal and institutional implications of changes in atmospheric moisture flows and their differentiated welfare consequences for communities around the world.

Instituting a just, global water-governance mechanism at the UN would incorporate a process of inclusive, multi-stakeholder dialogue and an agenda for collective action to accelerate impact. The ultimate ambition is to negotiate a global water pact with clear and measurable goals to stabilise the hydrological cycle and recognising it as a global common good. Leveraging the UN's legitimacy and structure to consolidate the Global Water Agenda, the recent appointment of a UN Special Envoy for Water (United Nations, 2024a) could structure leadership and we recommend appointing a youth water envoy to ensure an intergenerational approach. This could lead to creating a Governing Board consisting of key UN leaders to guide the Global Water Agenda and coordinate UN agencies' water-related work.

Implementing collaborative water governance involving multiple stakeholders, including (local) government agencies, NGOs, indigenous peoples, community groups, and business entities, in an intra- and inter-generational approach, would establish a collaborative process and engagement space connected to the global governance architecture, for consistent and continued accountability and engagement, and develop comprehensive understanding of water needs at all levels, aligned with the Just Water Partnerships objectives.

A strong and unified global water forum would provide a safe space for research, trust-building, capacity development, and accountability. Such a space would bring together all green and blue water processes and partners, and support political, cultural and policy dynamics.

We must improve education, knowledge, and awareness about: the hydrological cycle and water scarcity; agency for action at individual, institutional, and governmental levels; valuing water, acknowledging the spectrum of relationships between water and people, and linkages across sectors, geographies and generations; the major legal and institutional implications of changes in atmospheric moisture flows and their differentiated welfare consequences for communities around the world.

Strengthening water governance and establishing water authorities, where absent, would meet the overarching need to stabilise the hydrological cycle, with blue and green water governance at the heart of their missions.

Focusing on transboundary co-operation for both blue and green water would enhance collaboration and construct fit-for-purpose governance architecture to manage shared blue and green water resources sustainably and equitably.

Water challenges hurt most at the local level. Yet, the drivers of these local issues are increasingly global in nature. In the Anthropocene, even local water bodies are influenced by the hydrological cycle, and vice-versa. Human activities compromise the stability of the hydrological cycle, calling for a new approach to water governance that acknowledges these global-local linkages and serves a multi-scale framework for action.

We need to acknowledge the hydrological cycle as a global common good: it links countries and communities; it is deeply interlinked with the climate and biodiversity crises; and blue and green water play a distinct role in achieving almost all the United Nations (UN) Sustainable Development Goals (SDGs). With this acknowledgment comes an understanding and need to strengthen the architecture, institutional capacity, and interface of several global agendas, most profoundly: the three Rio Conventions on climate change, biodiversity, and desertification; the 2030 Agenda for Sustainable Development and the aligned Sendai Framework for Disaster Risk Reduction; the Addis Ababa Action Agenda on financing for development; and the Quito Declaration's New Urban Agenda.

Water as an organising principle

Water should be considered an organising principle for just sustainable development. Rather than each sector viewing water through its own narrow lens – which increases fragmentation, undermines water security, and hinders progress towards sectoral goals – we must adopt a perspective of "water and beyond", across all agendas and domains. A siloed approach fails to capture the many, multifaceted roles of water, and misses opportunities for synergistic solutions that fully address water's political and geopolitical ramifications. By redefining the world's relationship with water, we can more effectively address inconsistencies and trade-offs across interests and scales, and better navigate the delicate balance between environmental sustainability, social equity, and economic development towards transformative action.

Multilateralism faces significant hurdles. Shifting economic powers and geopolitical rivalries strain traditional co-operation frameworks. Growing emphasis on domestic priorities challenges the ethos of international collaboration. Still, multilateralism remains critical for solving the most pressing global challenges of our time – challenges that individual countries, cities, academic institutions, NGOs, or the private sector cannot address alone. Coordination among institutions, sectors, and actors on policy, regulation, and investment is meagre and stems from the complexity and diversity of local water contexts, since rights, perspectives, and interests regarding blue and green water can conflict. Coordination also lacks purpose and common ground. The call, therefore, is to reimagine mechanisms for dialogue, negotiation, and conflict-resolution – essential for securing peace, stability, and prosperity – where water and the protection of the hydrological cycle are front and centre.

Historically, compromise at the global scale has never been easy. But we must act now for the sake of the hydrological cycle's balance and all it entails. By being proactive rather than reactive, the international community can do much more than avoid the costs of constantly abusing its blue and green water (re)sources.

Improved understanding of the hydrological cycle creates a new and level playing field, positioning us to (re)shape our relationship with the natural world. Understanding and valuing blue and green water can structure efforts to put the necessary changes into practice.

Prosperity hinges on stabilising the hydrological cycle, with local success contingent on collective action at multiple scales. There is no one-size-fits-all solution to worldwide water challenges, and implementation will occur locally, guided by context-specific factors, management practices, cultures, and values (World Water Assessment Programme, 2019). . However, a fragmented approach will be inefficient to achieve change; addressing a global issue effectively requires coordinated action at regional and international level.

Cross-cutting and complementary solution frameworks applied to multiple jurisdictions, scales, and locations will be needed. Let us remember that many building blocks already exist: local, national, transboundary, and regional levels offer numerous examples of water governance systems, diplomacy, partnerships and coalitions, and social movements.

At the UN level, the 2023 UN Water Conference laid an ambitious groundwork for global water governance. On 13 September 2024, the UN Secretary-General (UNSG) appointed a UN Special Envoy on Water (United Nations, 2024). A UN System-wide Strategy for Water and Sanitation was launched in July 2024, and follow-up UN Conferences on Water were agreed upon (Resolution A/77/L.106[72]) and scheduled for 2026 and 2028. These conferences and their preparatory processes are critical opportunities to anchor water issues across the UN system, its agencies, and leadership.

In the past, many often-fragmented efforts were made to address the need for global water action. The 1977 UN Water Conference never had institutionalised follow-up, although its recommendations influenced many local to global policies and actions. Today momentum for global water governance and action is building. The UNSG's Advisory Board (UNSGAB) on Water & Sanitation and its role in scaling up actions for drinking-water and sanitation, followed by the High-Level Panel on Water, paved the way for global initiatives aimed at addressing water challenges and promoting sustainable water management. These include the Water Action Decade championed by the Republic of Tajikistan, the Kingdom of Saudi Arabia's Global Water Organisation, the United Arab Emirates' Mohamed bin Zayed Water Initiative on scarcity, and Senegal's Blue Fund for Development and Peace.

The momentum must be sustained, efforts integrated, and gaps addressed through a water-governance mechanism on the global agenda, with water positioned institutionally, accompanied by an organising and convening mandate, and capacity, with clear accountability standards. Existing initiatives must be expanded and supplemented to look beyond water supply, sanitation and hygiene (WASH), and water scarcity to consider the hydrological cycle as a global common good. A global water-governance mechanism is necessary to achieve a continuous and robust multilateral process, provide support and strategic guidance at all levels of implementation, and enable existing building blocks to yield collective action: local actions reinforcing national efforts; national actions empowering regional initiatives; and regional actions driving global progress. The international community must construct a fit-for-purpose governance architecture that facilitates collective and mission-driven action on water, and accounts for the legal and institutional implications of changes in atmospheric moisture flows, and their differentiated welfare consequences for communities around the world.

Opportunities to redesign water governance

Water at sub-national and sub-global levels

Achieving sustainable national and international governance of water is challenging due to its complex, interconnected nature and its spatial and temporal dynamics transcending geographic, administrative, and sovereign boundaries, compounded by the valuation of water as a natural resource – beyond a commodity – and as a human right.

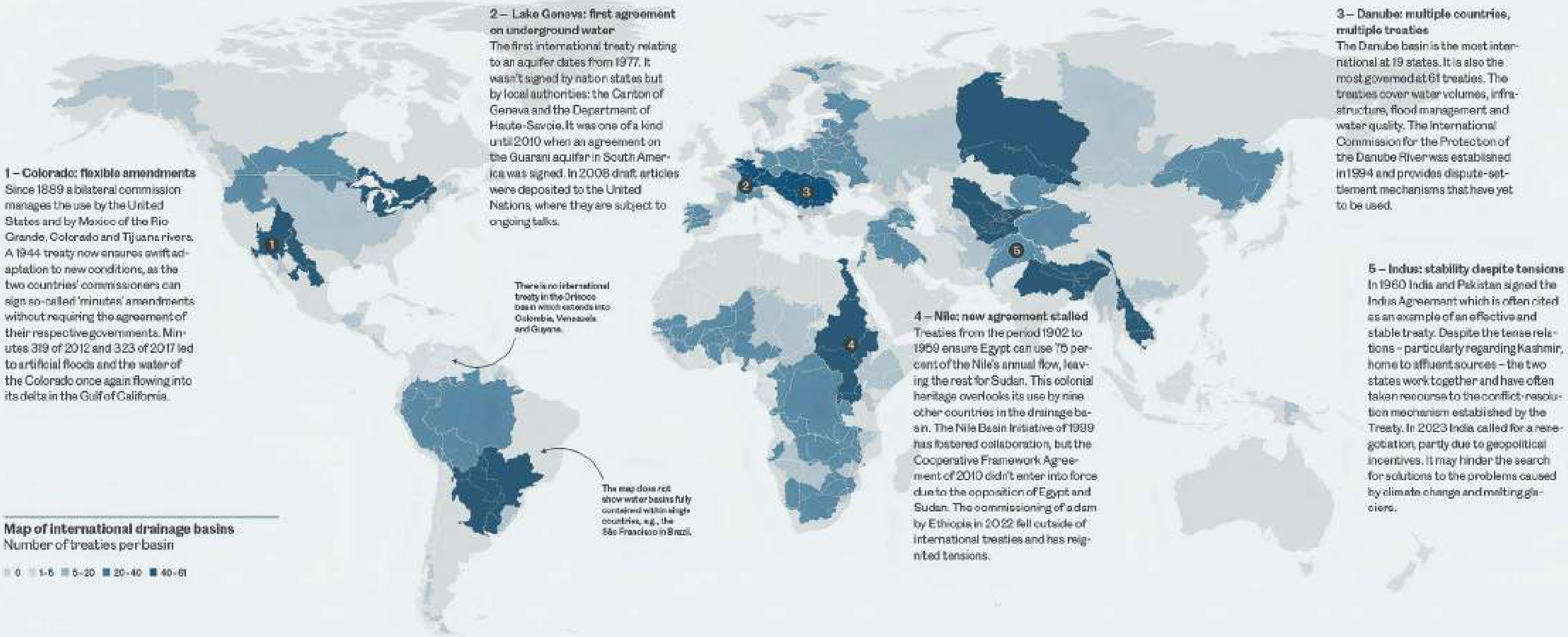
Consequently, water governance has operated across multiple scales, from river basins and aquifers to regional levels, encompassing a diverse array of structures and diplomatic initiatives. The remit and capacity of existing institutions, the value of context-specific experiences, and the presence of various governance arrangements should not be overlooked. These provide a wealth of knowledge – culturally, economically, and institutionally – and capacity that efforts on any scale can learn from and build on.

However, water governance, at regional and sub-national levels faces three grave challenges: fragmentation, failed coordination, and a lack of capacity (institutional, professional, and in partnerships), which can lead to inconsistent policies, overlapping jurisdictions, inefficient resource allocation, and communication gaps between stakeholders.

Water governance is also compartmentalised across different types of water, with most mechanisms designed for blue water and focusing on surface water. There is a lack of strategic orientation to address other forms of water, particularly green water. This misses the complex and dynamic relationship between blue and green water governance, including local perspectives on equity and justice, often linked to land and property rights (Groenfeldt, & Schmidt, 2013).

72 The Resolution was agreed upon at United Nations General Assembly September 1, 2023 (2023a)

FIGURE 10.1: Agreements in international transboundary river basins



Source: Oregon State University (2024)

While there is a shift in water governance in riparian states from a state-led hierarchical approach to more hybrid approaches incorporating participatory methods (Gupta & Dellapenna, (2009), there is a need for greater integration of these processes across scales (involving local and regional actors) and places (across the rural-urban continuum). Fractured governance remains a pressing issue, particularly in rapidly urbanising regions, and fragmentation within sub-national governance requires urgent attention.

At national level especially, it is crucial to expand notions of water governance and management to include land use, land management, and allocation activities, examining the implications of water and nature conservation hotspots beyond the conventional scope of (blue) watersheds.

At the sub-global level, governance faces obstacles due to the mismatch between political boundaries and hydrological cycles, though many examples of regional and transboundary water governance frameworks exist (Figure 10.1).

Globally, more than 263 river basins and 300 aquifers span the political borders of two or more countries (Global Water Partnership, 2015). . In the absence of coherent institutional frameworks to manage these shared water resources, local to regional conflicts over water allocation, pollution control, and infrastructure development have risen in the past, and if unchecked, this reality will become even more common. Sub-global water governance is necessary and requires effective coordination across multiple jurisdictions and country stakeholders – a need emphasised by the inherently global physical nature of the hydrological cycle.

Another issue arises from disparate capacity
Another issue arises from disparate capacity
and resources among different actors involved in transboundary water governance. Upstream and downstream countries often have divergent interests and unequal power dynamics, which can lead to inequitable water use and management practices. Additionally, the lack of standardised data collection and sharing protocols across borders can impede effective and transparent decision-making and planning for shared water resources. Consequently, the need for a global water data infrastructure is one of the key recommendations of this report (Chapter 9).

There is a lack of principles to guide collective action across scales towards enhanced stewardship of the hydrological cycle – especially the generative capacity of the water system, including green water, which is inherently tied to land-use patterns, property rights, and dimensions of sovereignty. This adds complexity to water governance, warranting a global dimension.
As a major governance gap, moisture recycling offers an opportunity for institutional innovation, international laws, and regulation. Countries should focus on understanding their role in the global and regional moisture cascade and dynamics,

and expand notions of water governance and management to include the influence of land use, land management, and allocation activities, examining the implications of water and nature conservation hotspots beyond the conventional scope of blue watersheds. Failure to address the full hydrological cycle would overlook its role in ecosystem and climate regulation, agriculture, and its feedback with blue water. Groenfeldt, & Schmidt, 2013). .

Developing global water governance structures that reflect evolving value systems while respecting national sovereignty and integrating the specifics of local dynamics and relationships, including local knowledge, remains a challenge. It will require dialogue, an action agenda, multilevel and multi-stakeholder working methods and institutional innovation – and the capacity to see it through.

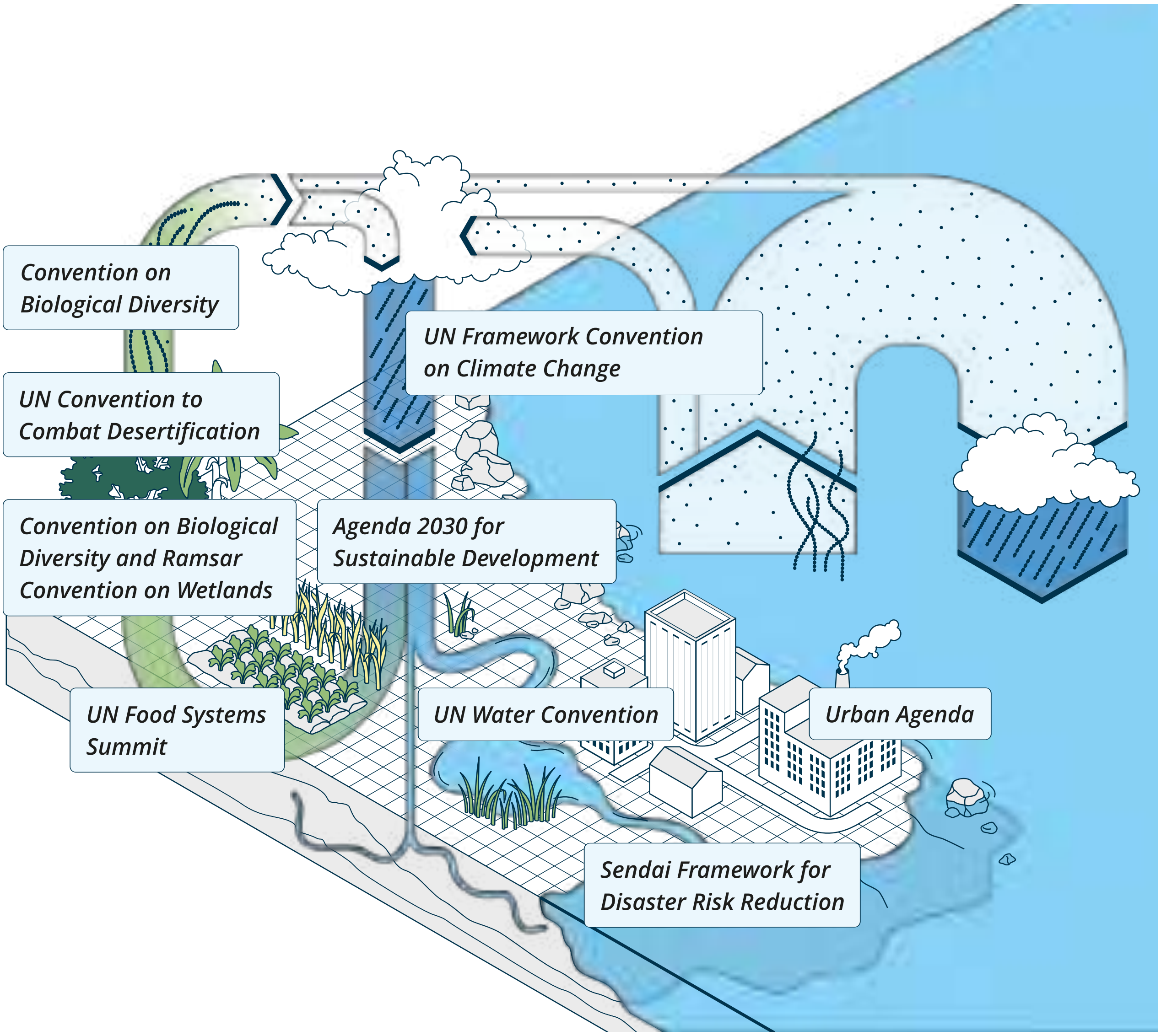
Water in the UN context

There is consensus that the UN system is not fully equipped to support the ambition of global water governance and the full, systemic, economy-wide implications for needed actions ¬– but that it should be. The UN Economic Commission for Europe (UNECE) Convention on the management of transboundary rivers and lakes is a notable achievement, successful in promoting transboundary water co-operation, albeit with too-limited reach. Its slow diffusion and enforcement are encouraging but point to the challenges of international collaboration and collective action on blue water.

Water features across multiple UN conventions and frameworks related to climate, biodiversity, wetlands, health, food systems, and disaster reduction, among others. It is also embedded in broader UN agreements and frameworks, including the 2030 Agenda for Sustainable Development, the UN Framework Convention on Climate Change (UNFCC), the Convention on Biological Diversity (CBD), the United Nations Convention to Combat Desertification (UNCCD), the UN Food Systems Summit, the Urban Agenda, and the Sendai Framework for Disaster Risk Reduction. Over 30 UN organisations carry out programs related to water and sanitation (UN Water, 2021). However, synergies between the three UN Rio Conventions (UNFCCC, CBD, and UNCCD) and the agricultural community are not fully exploited from the perspective of the hydrological cycle. Strategic alliances and adequate coordination must be strengthened to highlight the global character of precipitation and land interaction, as well as the critical role of green water for climate change.

UN agencies actively working on water are loosely coupled through UN Water, an inter-agency mechanism launched in 2003 with a limited mandate. This means that each agency contributes to UN Water on a voluntary basis, and on the capacity allowed by its own mandate, posing cooperation and coordination challenges due to simultaneous competition for resources and influence. UN Water, in its current mandate and capacity, is not able to reconcile these mandates around water across agencies.

FIGURE 10.2: UN agendas and the stages of the hydrological cycle



Note: The hydrological cycle and its fragmented representation across UN agendas are an opportunity to (1) strengthen water as an organising principle, (2) set a UN agenda across agencies and agendas, and (3) build a global water pact.

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Water at the Bretton Woods Institutions

The World Bank Group and the International Monetary Fund (IMF) are upgrading their approach to water. The World Bank has a long track record in the water sector. Its renewed ambition for water translates into an active Global Water Practice designed to deliver finance in the most dynamic countries through strengthened collaboration between the International Finance Corporation, International Bank for Reconstruction and Development, and the Multilateral Investment Guarantee Agency. The recently redesigned and repurposed 2030 Water Resources Group illustrates the ambition of the World Bank to accelerate action in selected countries through public-private partnerships. Writ large, the importance of a stable hydrological cycle plays out across the full portfolio of the World Bank. This is an opportunity, as emphasised throughout this report, that plays into the new mission of the World Bank: to “eliminate poverty on a liveable planet”.

Box 10.1. Efforts at an UN-level to promote water action

There has been an array of UN Initiatives aimed at consolidating and driving action on water issues in the past. Thes include:

- *The **Water Action Decade** (2018-28), launched on 22 March 2018, to accelerate efforts towards meeting water-related challenges and the SDGs (United Nations General Assembly, 2018).*
- *The **2023 UN Water Conference**, 22-24 March 2023, which marked a significant milestone in global water governance. Co-hosted by the Government of Tajikistan and the Kingdom of the Netherlands, it was only the second UN conference dedicated to water since 1977 [13]. It brought together over 10,500 participants and positioned water high on the global agenda. The Secretary-General's concluding remarks highlighted that "water as a common good [...] needs to be at the centre of the global political agenda." The Secretary-General also emphasised links across the 2030 Agenda for Sustainable Development, the justice and human rights aspects, the links with climate, and the need for UN leadership (Guterres, 2023). President of the General Assembly Csaba Korösi emphasised the need for water action in listing nine game changers (Kőrösi, 2023).*
- *The Conference adopted the **Water Action Agenda**, a collection of voluntary commitments from nations and stakeholders aimed at achieving water-related SDGs. The Water Action Agenda compiled over 800 commitments in the form of financial pledges, collaborative projects, and actions to protect water resources (UN Water, 2023).*
- *On 16 July 2024, the UN launched the **System-wide Strategy for Water and Sanitation**, which aims to enhance UN system-wide coordination and delivery of water and sanitation priorities across the UN system in support of countries to accelerate progress on national plans and priorities, internationally agreed water-related goals and targets, and transformative solutions to current and future water and sanitation challenges (UN Water, 2023).*
- *Looking ahead, **UN General Assembly resolution A/RES/77/334** (United Nations General Assembly, 2023b) agrees to organise two additional water conferences: one in 2026 to expedite the implementation of SDG 6, and another in 2028 to promote water-related actions and assess progress made during the International Decade for Action.*
- *Towards the COP29, and under the COP29 Presidency, the **Baku Dialogue on Water for Climate Action** was developed with support from the UNEP, UNECE, and WMO, with contributions from other UN Water members. The Baku Dialogue will be launched at the 29th Climate Change Conference (COP29) in November 2024 in Baku, Azerbaijan. The Baku Dialogue on Water for Climate Action will serve as a consistent and regular dialogue platform on water and its interplay with climate change, biodiversity loss, desertification, and pollution.*
- *T**he UN Transition Agenda** (https://unsdg.un.org/resources/six-transitions-investment-pathways-deliver-sdgs) outlines an integrated approach and investment pathways needed to fulfil the 2030 Agenda, navigating the synergies and trade-offs across the 17 SDGs. The UN Transition Agenda identified six key transitions for catalytic and multiplier effects across the SDGs:(1) food systems; (2) energy access and affordability; (3) digital connectivity; (4) education; (5) jobs and social protection; and (6) climate change, biodiversity loss and pollution (United Nations Sustainable Group, 2023). With the establishment of this UN Transition Agenda, the UN sets the stage for investing to deliver on the SDGs. Water runs as an organising principle through these six transitions.*
- *On September 22, 2024, the UN General Assembly adopted the Pact for the Future (United Nations, 2024b). The breadth of the Pact is welcome. Avenues towards transformation of global governance, including the global financial architecture, provide opportunities to factor in the hydrological cycle as a global common good. Water still features in the Pact, in a fragmented way. As argued in this report, considering the hydrological cycle would provide a clear reference to the water agenda and its contribution to areas covered by the Pact, most notably peace and security, sustainable development, climate change, human rights, gender, youth and future generations.*

Over the last decade, the IMF occasionally released seminal analyses on water (Kochhar et al., 2015). While recent developments on climate change and nature endeavour to consider how environmental risks affect inflation and financial stability, there is increasing evidence to support the macroeconomic case for improved water stewardship in the global economy. Water pertains to these discussions, as the hydrological cycle is both a driver and a victim of climate change, and because water and land-use are essential factors to mitigating environmental risks. The reform of the global financial architecture and the Paris Pact for People and the Planet provide opportunities to acknowledge water (and its multiple dimensions) as a driving force and part of the solution throughout global agendas, to promote system changes and the provision of multiple common goods.

Water at other international financial institutions and public development banks

International financial institutions and public development banks play an important role in financing achievement of the SDGs and other global agendas. Given water's centrality to all the SDGs, and the potential implications for human welfare of recent changes in the global hydrological cycle, these institutions are uniquely positioned to catalyse and scale up investments in water-related projects and initiatives that can have far-reaching impacts across multiple development goals. By leveraging and reframing their financial resources, technical expertise, and convening power, international financial institutions can mobilise additional funding from public and private sources, promote innovative financing mechanisms such as Just Water Partnerships, and support the implementation of integrated blue and green water management strategies that address interconnected and systemic challenges such as climate resilience, food security, and public health.

Most international financial institutions have a water strategy, usually in connection with commitments to address climate change. These cover water supply and sanitation. Acknowledging the evidence of a tilted hydrological cycle, they can also include blue water and related risks (floods, droughts, pollution). They rarely refer to green water. Items relevant to the management of the hydrological cycle, such as agriculture, land use, or urbanisation, are covered separately. Here there is an opportunity for multilateral and regional financial institutions to establish facilities dedicated to scaling quality investment in blue and green water to support countries' Nationally Determined Contributions and National Biodiversity Strategies and Action Plans.

At national level, public development banks are catching up. With their mandate to finance sustainable development and their knowledge of national specificities and opportunities, they are equipped to contribute to water governance and finance along the lines in this report. The most proactive ones gather in the Water Finance Coalition, providing opportunities to advance the blue and green water agenda in national development strategies and finance.

Water and trade

The linkages between trade and water are central to global water action. Trade agreements can set the stage for equitable and sustainable water productivity, and even minimise pressure on water resources when trade flows and their regulatory frameworks reflect the competitive advantage of countries – typically a larger endowment of water resources. Trade distortions emerge when the opportunity costs of using water in one country are not reflected in the price of traded goods, such as when water is undervalued and not properly priced, and subsidies weaken the price signal.

The World Trade Organization (WTO) plays an important role in advancing the SDGs, including those related to water and sanitation. By promoting stable and equitable trade relationships, the WTO supports sustainable development and addresses challenges such as water scarcity, pollution, and drivers that affect the hydrological cycle. Furthermore, the WTO cooperates with multilateral environmental bodies such as UNEP and others in a bid to ensure that trade policies are, to the extent possible, aligned with environmental sustainable development objectives.

Water-related issues have been discussed in various contexts within the WTO.[73] There would be some benefits in reviving them, considering the projected consequences of a tilted hydrological cycle on trade flows (Chapter 3):

- **Trade and water supply and sanitation services**. Reducing trade barriers could facilitate the transfer of water treatment and conservation technologies across borders. However, such liberalisation must be accompanied by strong regulatory frameworks to ensure equitable access and environmental protection. Under the WTO's General Agreement on Trade in Services (GATS), for instance, governments are expected to regulate water services and set standards for quality, safety, pricing, and other policy objectives. This ensures that when commitments are made, foreign suppliers would be subject to the same regulations as national providers. Fifty-two members have made commitments regarding wastewater treatment, but none have done so for water distribution services. This is because water services require costly infrastructure and are traditionally operated by local public authorities with limited room for competition. During the Doha Round of negotiations, some proposals aimed to expand commitments on water services – focusing on wastewater treatment – but these negotiations were inconclusive.

- **Trade and environmental good and services.** More recently, discussions under the Structured Discussions on Trade and Environmental Sustainability (TESSD) by 77 members have explored the scope of environmental goods and services. While these talks do not directly address water trade, trade in environmental products could facilitate the dissemination of water management and conservation technologies. This includes technologies related to water supply, pollution management, and wastewater treatment.

- **Virtual water trade and trade policies**. While the concept of "virtual water" has not been discussed in WTO bodies, it plays a significant role in understanding the water-trade nexus. Virtual water refers to the hidden flow of water used in the production of goods and services that are traded internationally. By importing water-intensive products, countries with scarce water resources can conserve their own water while meeting their needs for those products. Conversely, countries rich in water resources can export water-intensive goods, effectively exporting virtual water.

Trade in virtual water can be a powerful tool for global water management, promoting more efficient use of water resources worldwide. Efficient resource use relies on well-designed incentives. Just as economic gains arise when countries specialise according to their comparative advantage, environmental benefits can be achieved when water-intensive products are traded from water-rich to water-stressed countries. To ensure virtual water trade promotes efficient, equitable, and sustainable water use, domestic and trade policies must reflect the true value of water, preventing virtual water flows from exacerbating water scarcity or further tilting the hydrological cycle (through land-use change, for instance) in exporting countries. Properly designed trade agreements can balance virtual water trade, helping to achieve water sustainability on a global scale.

However, for trade agreements to play these roles effectively, domestic water pricing must accurately reflect the true economic, social, and environmental costs. Distortions occur when the opportunity costs of water usage are not considered in the price of traded goods, particularly when water is undervalued or subsidies undermine appropriate pricing signals.

Reforming and repurposing harmful agricultural subsidies also presents a critical opportunity to enhance water conservation. While irrigation subsidies directly affect water use, other subsidies, though not specifically aimed at irrigation, can indirectly steer producers toward water-intensive crops, often at the expense of more sustainable alternatives. Additionally, subsidies like input supports can promote the overuse of fertilisers, leading to soil degradation and the contamination of waterways. Reforming these subsidies through agricultural negotiations can therefore drive

73 Contributions from the *Brief on the economics and relevant policies of virtual water trade*, prepared by the WTO Secretariat for the GCEW. The views here reflect views of the WTO Secretariat and not of WTO members.

significant improvements in both economic and environmental outcomes by fostering more-efficient use of water and other resources.

To make water and trade mutually supportive, trade must promote economic efficiency, equity, and environmental sustainability. Achieving this requires new analytical and regulatory frameworks, and political platforms to address the political and economic challenges that hinder reform.

Water at the OECD

As an intergovernmental organisation, the OECD helps governments manage their water resources and deliver water-related services across economic sectors and policy agendas.

As an economic organisation, the OECD supports countries through economic analysis of water management. The current programme of work builds on several pillars:

- **Policies to prevent and manage water pollution.** The degradation of water resources affects ecosystems, increases water treatment costs, and worsens water scarcity. The OECD helps identify the economic and financial costs of water-quality degradation and identify effective pollution-management strategies.
- **Water finance.** The OECD documents financing needs and capacities across regions (most recently Europe and Asia). It supports active dialogues between the water and finance communities on new developments and options to finance water at scale (OECD, 2021). It also explores how to redirect financing flows that work against the Water Agenda, using analytics that document the materiality of water for corporates and financiers.
- **Water governance.** The OECD has identified twelve principles that characterise good water governance and can contribute to the design and implementation of such policies, where shared responsibility across levels of government and the broader range of stakeholders is explicit and compliance is encouraged.

OECD policy guidance on water is captured in the Recommendation of the OECD Council on Water (OECD, 2016), unanimously adopted by member states in 2015. The Recommendation provides guidance on managing water quantity, improving water quality, managing water risks and disasters, ensuring good water governance, and ensuring sustainable finance, investment and pricing for water and water services. Non-member countries are welcome to adhere to the Recommendation, signalling their willingness to align with good international practices.

New work inspired by the Global Commission on the Economics of Water (GCEW) can help countries and other agencies consider the value of the hydrological cycle and align policies and incentives with the ambition to stabilise it. This would require considering water in conjunction with biodiversity and ecosystems, climate change, land use and forests, and agriculture and trade (in collaboration with the WTO). A pilot on a major evaporationshed would test some of the key concepts and proposals of the GCEW. In co-operation with national and international partners, the development of Just Water Partnerships could ignite interest across jurisdictions. Support for UN efforts to revive interest in water accounts in line with the ambition of the GCEW would seem timely

The role of social movements in water governance

Social movements have significant power to push action on water issues, spread awareness, and contribute perspectives. Youth movements, Indigenous groups, and mass actions represent the exercise of rights and the voice of civil society, demanding a safe and just water future. These

movements help drive policy change, hold corporations accountable, promote the human right to water and sanitation, and bridge local and global issues.

Youth

With the future at stake now more than ever, we must put young people at the heart of championing water for the common good. Young people are the largest demographic group and, at times, the most affected by the consequences of an altered hydrological cycle. Therefore, they must be empowered to act on their own behalf to mitigate the water crisis.

Young people are not just tomorrow's leaders; they spearhead efforts to address water challenges today, demonstrating capacity for leadership. Youth's ability to communicate and mobilise public opinion, engage with policymakers, develop solutions to address water-related challenges, and maintain pressure on international forums, positions them as important stakeholders in dialogues, consultations, and decision-making. The establishment of the loss and damage fund during COP27 was influenced by youth advocacy and activism, demonstrating that advocacy from youth movements has successfully materialised before.

While there is a growing volume of youth water actors at all levels, engagement groups, and network associations face fragmentation, limiting their voice and influence. Further, youth movements face challenges such as a lack of funding, limited access to data and information, and insufficient continuity and formality – even as their agency is recognised and they secure seats at the table. At times, young people lack the avenues, platforms, and support to play their part in the development of strategies and policies aimed at protecting the hydrological cycle and defining how we govern water for the common good.

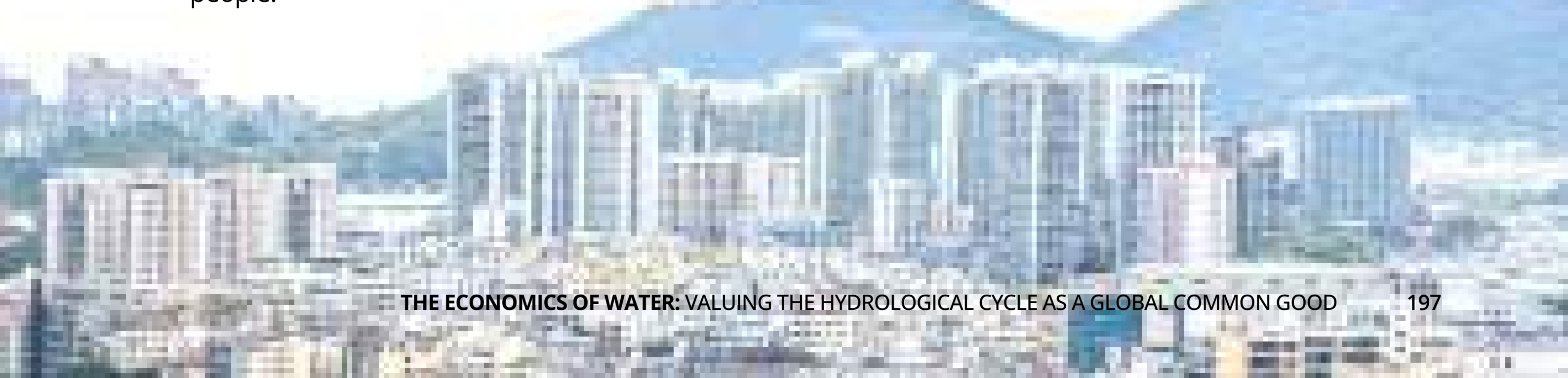
Therefore, fostering intergenerational action on water issues is essential: leveraging the experience and resources of older stakeholders while harnessing the energy, stake, and ideas of young people.

Numerous youth networks engage in water governance at local, regional, and international levels, and have support from "traditional" stakeholders:

- Youth-led commitments in the Water Action Agenda were pledged to address water-related challenges at the 2023 UN Water Conference. Of the 700 commitments included in the Agenda, more than 400 involved youth. Tajikistan pledged to use the Dushanbe Water Process as a follow-up mechanism to ensure youth involvement in global water discussions, and Grundfos, along with 16 other companies, committed over USD 11 billion to support investments in innovation and youth engagement over the next five years (Espindola, 2023).

- The Youth Declaration and Plan of Action was developed by the United Nations International Federation of Youth for Water and Climate, mandated by the co-hosts of the 2023 UN Water Conference. This plan consolidates the inputs of young people, highlights youth perceptions, evaluates their awareness of water and climate issues, identifies challenges, and formulates recommendations in the form of policies, projects, programmes, and activities (UN1FY, 2023).

- The Global Youth Movement for Water connects over 300 youth-led organisations and allies from 70 countries, working to influence decision-makers, increase youth negotiating power, and encourage action on water-related issues globally. Launched during the 9th World Water Forum, this movement aims to amplify the voice of the younger generation and mobilise youth from local to global levels. By fostering collaboration and synergies among various youth organisations, the movement enhances their collective outreach and impact (YMW, 2023).



Against this backdrop and the findings in this report, the GCEW, is keen to continue empowering youth leaders, activists, innovators, entrepreneurs, and champions to be at the forefront of valuing and governing water for the common good.

An example of the latter is the Youth Water Agenda, launched at the 10th World Water Forum in Bali, Indonesia, under the auspices of the GCEW. The vision of the Youth Water Agenda is to be a catalyst, facilitating the structuring and mainstreaming of youth to advocate and participate in shaping water security and governance.

The report offers the Youth Water Agenda focus areas allowing youth across multiple sectors to engage in water issues in their contexts, supported by strategic and collaborative platforms and partnerships, ensuring that youth contributions and impacts transcend boundaries. It is paramount to ensure that young people, regardless of their age, sexuality, race, gender, background, or disability, can contribute to the conversation as we are fighting for water for the common good.

Indigenous Peoples

Indigenous Peoples are stewards of ecosystems, and blue and green water flows in their territories. They are stakeholders and rightsholders who bring unique knowledge and perspectives on water. Incorporating their epistemic knowledge and agency into global water governance is critical to address water-related issues and to be faithful to the principle of recognition justice. In global fora, Indigenous Peoples have been prominent on issues related to climate change, nature, and biodiversity:

- The UN Permanent Forum on Indigenous Issues constitutes the largest global annual gathering of Indigenous Peoples and is an advisory body to the UN Economic and Social Council, mandated to address issues related to the environment, among others (Resolution E/2000/22[74]).

- The Indigenous Peoples Global Coalition Commitment for the UN Water Action Agenda was adopted in anticipation of the 2023 UN Water Conference (United Nations Department of Economic and Social Affairs n.d). The Agenda aims to include Indigenous People's rights and knowledge in the development and implementation of international plans, bodies, and programmes to protect and manage water in response to the climate crisis.

Representatives of different Indigenous Peoples face barriers to participating in governance processes that affect Indigenous livelihoods and rights, such as limited financial and non-monetary resources, language and lack of inclusion. It is important to note that these hurdles take place against a backdrop of a wider set of systemic challenges related to land property rights, access to credit, acknowledgement of traditional lifestyles and knowledge, conflicting uses of water sources, deforestation and extractive activities in indigenous territories, among others.

Mass-action campaigns

Privatisation of water services and sanitation, water tariffs, corporate exploitation of water resources, violation of indigenous rights, and lack of citizen consultation have led to mass-action campaigns around the world that demand government and stakeholder accountability. Justice is often invoked as a prominent driver for such social movements:

- The Right2Water campaign was born in Ireland in 2014 with the abolition of water charges and "Irish Water" as the primary objective. The Right2Water trade unions facilitated nine of the largest protests Ireland had ever seen, with over one million people. The campaign forced several policy changes on domestic water charges (EWM, n.d.).

- In 2000, thousands of Bolivians protested water privatisation and rate hikes, leading to the Cochabamba Water War Baggerman & Davalillo-Hidalgo, 2021) .

- A mountain village in Tunisia protested a quarry operation that contaminated the Khumayr tribe's only water source, leading to allegations of government neglect [32].

- Citizens in Chiapas, Mexico, collectively demanded government action to stop "Big Soda" corporations from draining public wells (Baggerman & Davalillo-Hidalgo, 2021).

74 The Resolution E/2000/22 was introduced in the ECOSOC 45th plenary meeting, 28 July 2000 (Economic and Social Council, 2000)

- For decades, South Africa has seen ongoing water-related protests and riots in certain townships (Baggerman & Davalillo-Hidalgo, 2021).

As climate change accelerates, water-related challenges will intensify, increasing strain on water governance systems and fuelling social movements. To address water-related tensions and improve water governance, it is critical to acknowledge social movements and create platforms that can combine independent but related issues around the hydrological cycle. The Water System Justice approach offers a framework to structure discussions around water-related justice issues.

Environmental NGOs

Non-governmental organisations (NGOs) play a critical role in advancing global water governance. Their involvement ensures that the voices of marginalised communities, environmental concerns, and public accountability are represented in decision-making processes relative to the protection of the hydrological cycle. Non-governmental organisations bring expertise, advocacy, and operational capacity to water governance efforts, often working at the intersection of local, national, and global levels. They engage in a wide array of activities, from community-based water management programme to influencing international water policy frameworks.

Non-governmental organisations have been pivotal in raising global awareness about water scarcity, pollution, and the need for sustainable water management practices. Through campaigns and advocacy, they have brought attention to the urgency of stabilising the global hydrological cycle and its implications for climate change, biodiversity, and human health. Moreover, their work transcends mere awareness, as many non-governmental organisations actively engage with international bodies such as the UN, World Bank, and regional organisations, and with corporates, thereby contributing to water governance at multiple scales. Their involvement ensures that environmental justice, human rights, and sustainability are integrated into global water strategies. They are also watchdogs, monitoring the actions of governments and corporations to ensure compliance with international water governance standards. By holding stakeholders accountable, non-governmental organisations safeguard the interests of the public and the environment.

Unlike global-scale organisations, non-governmental organisations often work closely with local communities, which allows for effective trust-building with local communities. This becomes a symbiotic relationship as they also promote capacity-building at a local scale to ameliorate water management. By training community members and supporting local governance structures, non-governmental organisations empower people to take charge of their water systems, fostering ownership and sustainability.

Non-governmental organisations are called to collaborate with local, national, and international organisations if a coherent global water governance framework is to be developed; especially by promoting Just Water Partnerships. By fostering these types of partnerships between diverse actors, non-governmental organisations will deliver governance mechanisms that are inclusive, participatory, and aligned with the principles of sustainability and justice.

Water and the private sector

The private sector plays a critical role in addressing global water challenges through corporate governance initiatives, responsible supply-chain management, technological innovation, operational efficiency improvements, and sustainable investing. Companies increasingly recognise water-related business risks and engage in corporate water stewardship to mitigate them and promote sustainable water management [34]. Moreover, they are working with other corporates, governments, and civil society to elevate water issues on companies' agendas, advance collective water stewardship, and provide platforms for innovation, partnerships, and exchange of best practices.

Examples of initiatives where the private sector is addressing global water challenges:

- The Global Water Initiative by the World Economic Forum aims to scale a new generation of public-private partnerships to protect the world's freshwater ecosystems.
- The UN Global Compact's CEO Water Mandate mobilises business leaders to

advance water stewardship, sanitation, and the SDGs. Participating companies commit to continuous progress against six elements of stewardship and report on their efforts annually.

- The Water Resilience Coalition, an industry-driven, CEO-led coalition of the CEO Water Mandate, aims to elevate global water stress to the top of corporate agendas and preserve the world's freshwater resources.
- The 2030 Water Resources Group, a public-private-civil-society partnership hosted by the World Bank Group supports country-level collaboration to unite diverse groups with a common interest in the sustainable management of water resources.
- The Alliance for Water Stewardship is a global membership collaboration that promotes responsible use of freshwater through its International Water Stewardship Standard. The Alliance works with companies, NGOs, and the public sector to drive collective responses to shared water challenges.
- The World Business Council for Sustainable Development's Water Solutions initiative is a business-led programme that develops tools and partnerships to support companies in implementing water stewardship strategies and achieving water security.
- The Water Footprint Network is a platform for collaboration between companies, organisations, and individuals to solve the world's water crises by advancing fair and smart water use.

The water-related missions set out above provide actionable ambitions to drive and gauge the capacity of these initiatives to transform corporate practices and value chains.

Public-private partnerships integrating the conservation, restoration and sustainable use of blue and green water in contractual arrangements can further catalyse such action. Synergies can be exploited with action in the field of climate change mitigation and nature conservation. The field of materiality of climate, nature, and water risks for corporates and financial institutions is a cogent illustration.

Water and academia

Academia plays an essential role in ensuring informed water governance and programming across geographical scales by providing the scientific and historical (Dellapenna & Gupta, eds., 2021) knowledge and data necessary to develop effective policies, manage water resources sustainably, understand complex water systems, and identify innovative solutions to address emerging water challenges. Research institutions are also key strategic partners in co-designing and achieving missions thanks to the generation of data, and providing expertise as well as driving policy and technical innovation. Incentives should be put in place that support the integration of science-policy interface mechanisms in water-related governance processes.

The effects of a tilted hydrological cycle – driven by the Anthropocene – have not yet been fully understood. There is an urgent need to explore the unpredictable nature of this new cycle and how global societies must adapt to living within it while preventing its further destabilisation. Furthermore, academia must address the question of how innovation – particularly in sectors like agriculture – impacts the destabilisation of the hydrological cycle. Applied research, coordinated across institutions globally, is essential to understanding whether current innovations genuinely contribute to sustainable water management. Governments have a role in moving the frontiers of R&D, steering the focus and direction of collective efforts, and bringing together multiple knowledge systems to purposely tackle the challenges ahead.

Researchers must take a multi-causal approach to understanding global to local hydrological changes, identifying who causes and benefits from the alteration of the hydrological cycle, and unpacking how, when, and why certain values and interests might or might not translate into sustainable policy and practice. This requires investing in new explanatory capacities and data collection practices at localised and global levels, particularly regarding moisture flows and the quantification of exposure to hydrological imbalances in terms of people, the economy, and biodiversity.

Moreover evidence-based decision making, identifying emerging issues early, and developing innovative solutions are key. Together with capacity building, policy analysis and advocacy, and community engagement, academia plays a pro-active role in the future orientation and integration of sustainable water governance across societal dynamics, cultural boundaries, and geo-political constraints. A key component of this role entails equipping students across disciplines with knowledge and skills that enable young professionals to advance a systemic understanding of water-related challenges within their respective fields, and to foster innovative solutions.

Creating a safe space, programming for ongoing research, capacity development, and testing organisational innovations will be key to strengthening local to global water valuation and governance.

Towards a global water pact

The GCEW has offered five missions to solve blue- and green-water-related challenges.

Through a process of inclusive and multi-stakeholder debate, negotiation and decision, an implementation agenda, reporting, and action, the international community can catalyse the adoption of these missions by country, organisation, and coalition, ensuring their timely achievement.

While many institutionalised agendas exist to carry out these missions, there is a lack of overarching and enabling institutional capacity. Without it, an ever-more fragmented approach will dominate. Taking into consideration the interdependence and interconnectedness among countries evidenced in this report, we need to value, stabilise, and govern the hydrological cycle as a global common good through co-operation, coordination, and shared responsibility. As such, institutional capacity on water by a global governance mechanism is required to support preparation of the 2026 and 2028 UN conferences, sustain post-2028 UN dialogues, ensure policy follow-up, implementation, and accountability, and provide leadership for a global water agenda while respecting national sovereignty and water jurisdictions.

Box 10.2: Towards a convention to manage vapour flows and the hydrological cycle

The 1979 UNECE Convention on Long-Range Transboundary Air Pollution (LRTAP) offers a precedent of global water governance for the common good. The Convention emerged after scientific evidence demonstrated that acid rain in one country was triggered by air pollutants emitted thousands of kilometres away. Noting that collective action was more effective and cost-efficient than domestic responses, countries in the pan-European region signed the UNECE convention in 1979 – the first international treaty to deal with air pollution on a broad regional basis. The Convention laid down general principles and set up an institutional framework for international co-operation for air pollution abatement. Further refinements unfolded to cover a rising number of polluting substances, enhancing the policy framework with evidence-based studies. This endeavour is considered a success and illustration of the benefits of international co-operation.

Just like LRTAP, vapour travels long distances and connects evaporationsheds with precipitationsheds across continents and beyond. These flows must be maintained to stabilise the hydrological cycle and rain patterns downwind. Hence, the UNECE convention offers several lessons that could inspire a legal instrument to manage green water and the hydrological cycle:

1. *The Convention is based on robust scientific research proving how emitters and recipient countries are connected through clouds and air flows, sometimes across thousands of kilometres. The Convention later provided a platform for scientists and policymakers to exchange information, supporting innovation, mutual trust, and learning.*
2. *The Convention was initiated at a regional basis as it became clear that localised approaches would be inefficient in addressing this issue. With time, other parties joined.*
3. *The Convention was subsequently supplemented by various protocols, focused on selected substances. The initial framework was wide enough to allow for adjustments and additions as new evidence developed, which in turn enhanced and improved the policy and its goals.*

Other approaches are currently underway. A multidisciplinary research project is being led by the Collège de France, the University of Geneva, the Geneva Water Hub and the University of Mekele (2024-2027), called Legal Perspectives on Atmospheric Water (Regards croisés sur l'eau atmosphérique). The project recognises that legal status, management, and protection of atmospheric water remain undetermined because international law deals very little with atmospheric water, and are only indirectly covered by international environmental legal instruments. It will map out this little-known territory from a wide range of disciplinary angles, with an emphasis on international law.

In this vein, the GCEW recommends capacitating unified action on water at the UN level. Leveraging its legitimacy and structure, and the momentum on global water action, the UN must lead in the consolidation of the Global Water Agenda. This agenda should be symbiotic and synergistic with the SDGs and the Paris Agreement, build on a shared set of principles inspired by the outcome of the 2023 UN Water Conference, and act as an organising principle to unite the uncoordinated processes, agendas, and solutions that feature water. To raise the visibility and urgency of succeeding on these vital missions, the GCEW supports the recent appointment of a United Nations Special Envoy on Water. Additionally, the GCEW encourages the UN to appoint a youth water envoy to ensure a formalised, intergenerational approach.

Rather than creating a UN agency specialised in water that risks reinforcing a siloed approach, the GCEW recommends to establish a Governing Board consisting of: (1) the UN Deputy Secretary-General (also in their capacity as chair of the United Nations Sustainable Development Group); (2) the UN Special Envoy on Water (mandated by the UN Secretary-General); (3) the Under-Secretary-General of the UN Department of Economic and Social Affairs; and (4) the Chair of UN Water. This quartet can prepare and guide the roadmap towards the 2026 and 2028 UN Water Conferences, the Transversal Water Agenda for the Six Transitions of the Investment Pathways to Deliver the SDGs, and the preparation of the post-2030 Agenda. Additionally, this quartet can coordinate the designated UN agencies on their water work for their dedicated UN agendas and meetings, and the development of a unified UN Water Agenda.

By leveraging this untapped agenda and bringing water to the forefront of global discussions, we can begin to forge a more integrated and effective approach to global water governance. This strategy will acknowledge and bolster existing commitments and progress on multiple global agendas, and set the stage for a cohesive, fit-for-purpose and transformative global water governance mechanism. A global water governance mechanism would ensure a comprehensive strategy for collective action where rights-holders and stakeholders are given an institutionally mandated participatory role.

The ultimate ambition of an interinstitutional approach for a Global Water Agenda should be the establishment of a global water pact. This pact would work under clear and measurable goals to stabilise the hydrological cycle. If appropriate, the five missions previously posed could provide a framework for action. An enabling condition is the GCEW's recommendation for a global water data infrastructure, which would allow monitoring, verification, and reporting; ensure transparency; and support the development of further scientific efforts and evidence.

Convening capacity beyond institutional settings will be the cornerstone for successful institutionalisation, alongside institutional capacity, leadership, and the mandate needed at all levels from local to global, with a clear focus on the UN and its role in the global water agenda. A safe space – a global forum for water (economics) and beyond – will have to bring together all processes, partners, and political, cultural and policy dynamics necessary for research; building trust, capacity, and accountability; exploring partnerships; testing

innovations; and sparking dialogues across the many divides, interests, backgrounds, and needs. Beyond this report, beyond the missions and the prompting of institutional action, this forum can be fertile ground for next steps.

Recommending unified, global, formal and informal water governance is not merely an aspiration, it is an imperative for survival and for lasting prosperity on our planet. Only through concerted, collective effort will we address the complex water challenges and safeguard the hydrological cycle.

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Box 10.3: The untapped UN Water Agenda

The UN can build on the established and agreed System Wide Strategy to anchor water in the UN system, by:

- *Anchoring water in all related upcoming UN conferences and meetings. On the road to the 2026 UN Water Conference, the sequence of UN meetings includes the COP16 on biodiversity, COP29 and COP30 on climate, COP16 on desertification, the third Oceans Conference, the Finance for Development Summit, the Food Systems Summit, and the 2nd World Social Summit. All of them present stepping-stone opportunities in the preparation of the 2026 UN Water Conference.*
- *The UN Agencies that support these conferences and gatherings should work together under the guidance of the quartet and actively support the presidencies of these conferences to deliver:*
    - *an outcome document as input for the 2026 UN Water Conference*
    - *organising a dedicated moment or day for that preparation*
    - *anchoring the outcome (the input for the 2026 UN Water Conference) in the concluding declarations of the subsequent meetings*
- *The development of new Nationally Determined Contributions and National Biodiversity Strategies and Action Plans provides an opportunity to reflect the benefit of investing in blue and green water to mitigate climate change and biodiversity loss. To support increased drought and flood resilience, National Adaptation Plans can benefit from prioritising the role of nature in conserving and regulating blue and green water.*
- *The 2026 and 2028 UN Water Conferences should serve as focal points for reporting and consolidating water-related commitments and progress from these various global frameworks.*

11. Conclusions

To effectively tackle the water crises, we need to consider the full implications of the hydrological cycle, the combination of green and blue water, that has consequences for communities and economies around the world and all the earth's ecosystems, affecting our collective ability to achieve local, national and global agendas in relation to dignified lives, food security, sustainable development, and more.

This report supports a new perspective on the way we value and govern water as a global common good. A perspective that recognises a stable hydrological cycle as a condition to achieve our most important social, economic and environmental goals. A perspective that combines economic efficiency, social and economic equity, and environmental sustainability, knowing that achieving each of these pillars requires that the other two are realised as well.

The GCEW has identified 5 critical mission areas, which together can guide action towards addressing a growing water crisis and stabilising the hydrological cycle so as to secure its benefits. They are open for further deliberation and adaptation, to favour ownership in diverse jurisdictions:

A. Launch a new revolution in food systems to improve water productivity in agriculture while meeting the nutritional needs of a growing world population.

B. Conserve and restore natural habitats critical to protect green water.

C. Establish a circular water economy, including changes in industrial processes, so that every drop of used water generates a new drop through reuse.

D. Enable a clean energy and AI-rich era with much lower water intensity.

E. Ensure that no child dies from unsafe water by 2030, by securing the reliable supply of potable water and sanitation for underserved communities.

A distinctive feature of missions is the emphasis on the role and capacities of governments to shape markets so that they become radically more sustainable in the way they affect the hydrological cycle through water and land use. Governments – national and local – can do so by mobilising a range of instruments and designing partnerships that deliver public value.

The solution space mapped in this report considers the role of innovation across missions, and the conditions for the expected benefits of innovation to materialise. Partnerships have the potential to mobilise the capacities of a range of agencies, with risks and rewards that are shared fairly. There is in particular a critical need to combine policy, financial and social instruments to unlock investments for water security, catering to each country's needs.

Indeed, finance is part of the solution, with the need for both early-stage and patient finance, and for public and private finance to be brought together to contribute to our critical water missions. More must be achieved through public and development finance, through country-tailored, programmatic (not only project-based) approaches, in line with national development strategies – with particularly important roles for public development banks.

Water service providers are key institutions to deliver on the five missions. They deliver best if a wide range of technological, organisational and governance options are considered, which put public value and those most in need centre stage.

The GCEW recognises the role of publicly available and interoperable data to underpin policy and investment. Corporate finance and financial markets would benefit from robust assessment and disclosure of the physical and financial materiality of water risks, taking account of the full hydrological cycle. The GCEW recommends a global water data architecture as one of the key components of new global governance arrangements for the hydrological cycle. So far, international collaboration has focused on the management of transboundary rivers and lakes, a most needed endeavour. Consideration for the full hydrological cycle calls for similar efforts on green water flows. Could inspiration stem from efforts to mitigate long-range transboundary air pollution, an area with more than 40 years' experience in international cooperation to manage clouds and rainfall?

Beyond Dublin. A set of principles to value and govern water for the common good

The work of the Global Commission on the Economics of Water builds on a prior recognition of the economic value of water. In 1992, participants in the International Conference on Water and the Environment endorsed the Dublin Statement, which is famous for acknowledging that economic value of water. The Dublin statement entails other messages, which resonate with the work of the GCEW. For instance, it refers to water and land resources conjointly: "management links land and water uses across the whole of a catchment area or groundwater aquifer". It requests "a greater recognition of the interdependence of all peoples, and of their place in the natural world". It calls for action programmes on water and sustainable development.

The Dublin statement offers a lot of food for thought. It also faces some imitations highlighted by the work of the GCEW. Consider the 4 principles below, from the Dublin statement (ICWE, 1992).:

- ***Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment.*** This includes "the basic right of all human beings to have access to clean water and sanitation at an affordable price." This is one step towards the human rights to water supply and sanitation, which were recognized by the UN General Assembly and the Human Rights Council in 2010. This however does not provide for a dignified life, as multiple water needs - for food and more - are not considered.

- ***Water development and management should be based on a participatory approach, involving users, planners and policy makers at all levels***. The emphasis is set at local level, with decisions "taken at the lowest appropriate level." While the multiscale approach is appropriate, the reference to the global level is missing.

- ***Women play a central part in the provision, management and***

safeguarding of water. This recognition is welcome. The GCEW emphasises that similar recognition should be awarded to communities that play a decisive role in green water management – most notably indigenous people – and generations that are affected by decisions made today; hence the youth and intergenerational agenda that accompanies the work of the GCEW.

- ***Water has an economic value in all its competing uses and should be recognized as an economic good***. Managing water as an economic good "is an important way of achieving efficient and equitable use, and of encouraging conservation and protection of water resources." The GCEW acknowledges that robust economics for water management can deliver economic efficiency, social equity and environmental sustainability (the 3Es). It emphasises however that new economics is required, that considers the value of both green and blue water, and that informs a mission-oriented, water system justice approach to water.

Going beyond the Dublin statement, and informed by the latest characterisation of the hydrological cycle and refinement in water economics in this report, the GCEW offers a suite of principles that are fit for current and future challenges. They provide the basis for further discussion and refinement.

- The hydrological cycle, encompassing both blue and green water, has to be governed as a global common good, through concerted action in every country and collaboration across boundaries and cultures.

- There are absolute limits to the total amount of water that can be safely and sustainably consumed globally.

- Water must be an organising principle for the transformations required to achieve collective ambitions on sustainable development and global environmental ambitions, regarding climate change, biodiversity and desertification.

- Economic efficiency, social equity, and environmental sustainability are mutually supportive. They can only be achieved through a range of policy packages, because no single policy alone can achieve the three of them.

- Water must be priced, subsidies allocated, and regulations shaped to support both efficient water use and access for all. Further, the full value of water's ecosystem benefits, including those deriving from green water, must be built into decisions on land use and protection of natural habitats.

- We should also shift from fixing externalities after the fact to shaping economies, so that green and blue water is used efficiently, equitably, and sustainably from the start.

- An outcomes-focused approach centred on our most important and interconnected water missions, must drive coordinated actions by governments, the private sector, and communities.

- Every human being needs water for a dignified life, estimated at 4000 litres per person per day. This estimate needs to be refined, promoted and achieved.

In line with the ambition of the GCEW, these principles are set to address the water crisis and – beyond - contribute to our global agendas. We hope they can inspire discussions and debates, that inform the preparation of forthcoming UN 2026 Water Conference.

Future work

The GCEW offers a process to continue the work initiated during its 2-year mandate, building on the momentum achieved through multiple conversations, active engagement and participation in diverse international fora on water and beyond. In particular, the five missions sketched in the report are meant to be actionable and inspiring, and to rally support across policy communities and communities of practice. Work can continue along two mutually supportive avenues:

- Further engagement with distinctive communities
- A research agenda.

Further engagement with distinctive communities

Beyond the report, the GCEW was always keen to engage with agencies that have the capacity to move the agenda further, in line with some of the analytics and recommendations in this report. We consider the communities below as essential to move the needle and take action at the appropriate scale.

- **Youth.** The solutions to the issues laid out in this report need to factor in the preferences and capabilities of people who will be affected by the consequences of the decisions made today: the youth and, as much as possible, future generations. There will be trade-offs. Decision making is more effective when it reflects that intergenerational dimension. For these reasons, the GCEW engaged with youth movements to contribute that intergenerational perspective. it supported the Youth Water Agenda Campaign (Global Commission EW, 2024), launched at the 10th World Water Forum in Bali, Indonesia. Distinctive contributions relate to the modalities to achieve intergenerational justice and to bolster Youth empowerment.
- **Indigenous communities.** The diagnosis and the solutions need to factor in the preferences and capabilities of people and communities that are at the front line of managing green and blue water, and the ecosystems that support the hydrological cycle. While the GCEW has documented the distinctive role and capabilities of indigenous people, it did not have the resources to meet these conditions in its 2-year mandate. It is however committed to initiate and encourage further engagement, which should be part and parcel of developments, refinement and implementation of the principles and recommendations offered in this report. Preliminary engagement with potential partners paves the way towards valuable developments.

A research agenda

The work initiated over the last two years calls for further research and refinement. A research agenda can pave the way for another decade of valuable, policy-relevant research. Some of the distinctive features include:

- Data, on total water storage, exposure to water stresses and hydrological imbalance, socio-economic data. Chapter 3 emphasised the relevance of the concept of total water storage, to support evidence-based policies. The accuracy, granularity and comparability of available data across regions are conditions for place-based and just responses.
- The economics of moisture, with a view to better characterise action to preserve moisture in soils. This report sheds light on the value of keeping moisture in soils, from a water, climate mitigation and biodiversity perspective. More work is required to support effective action at the appropriate scale, including evaporation-sheds.
- More work is required on what the operationalisation and application of the Water Systems Justice framework, as outlined in Chapter 4, would look like, for example regarding the renegotiation of existing water contracts and incorporating different perspectives in policy responses.
- The benefits of innovation in each sector for the hydrological cycle, and the conditions needed to ensure they can succeed and be scaled up. Chapter 5 in particular documents a burgeoning field of innovation to deliver on the five missions that can help address the water

crisis, as characterised in this report. Empirical work can help document the conditions to speed-up deployment, while avoiding unintended consequences.

- Allocation regimes that ensure a just allocation of water resources, and the conditions to transition towards their implementation. The reform of water allocation regimes is notoriously complicated, because of vested interest and political economy issues. Lessons from practical experience can be beneficial for a wide audience.

- Refinement of the projection of water needs for a dignified life. The calculation in Chapter 4 is based on assumptions that can be refined. This would help define and document justice issues in relation to access to water globally, and support the need for global responses.

- Towards principles for Just Water Partnerships. Just Water Partnerships have the potential to support the development of place-based transitions towards policies and practices that contribute to stabilising the water cycle. In essence, they provide the platform for the iterative design of such transitions, their implementation, with the support of financing strategies. More work is required to characterise Just Water Partnerships. Typically, it would seem appropriate to develop a set of principles to guide the development and replication of such partnerships. It would be particularly appropriate to explore how such Just Water Partnerships could operate at the level of evaporation-sheds, supporting cooperation along the hydrological cycle.

- Aligning trade with the ambition of restoring a broken hydrological cycle. Trade, most specifically the trade of goods and rely on freshwater for their production, can contribute to effective water reallocation globally. The conditions are well known. Vested interests and political economy issues make the realisation of these conditions complex. Informed by new economics of water, and inspired by the recent agreement on fisheries, an international effort can move the needle and illustrate the possibility of international cooperation in that domain.

Work towards implementation of the recommendations, or operationalisation of some of the principles sketched in this report, would benefit from an experimental attitude. We recognise how context-specific solutions can be, typically when it comes to driving behavioural change for farmers, water or land managers. Trial and error are part of the experimental process, when lessons are learned from successes and failures.

A related suggestion: narratives are powerful mechanisms to inform and drive policy and behaviour change. While the GCEW has focused on facts and evidence to inform such narratives, culture is the ultimate medium to form and disseminate them. This piece of work would benefit from attempts by story tellers to transform it into vernacular art forms that reach communities around the world. This would demonstrate a fascinating alliance between science, policy and culture to drive change.

Recommendations

The GCEW offers a set of recommendations, to value and govern water so as to stabilise the hydrological cycle, enable food security and human dignity, and keep the Earth system safe for humanity. Underpinning all our recommendations is the need for justice and equity to be key principles intrinsic to managing water more efficiently, dynamically and sustainably, and not merely an add-on.

1. We must **govern the hydrological cycle as a global common good**, recognising our interdependence through both blue and green water flows; the deepening interconnections between the water crisis, climate change, and the loss of the planet's natural capital; and how water flows through all our 17 Sustainable Development Goals.

2. We must **recognise the minimal water requirements of water for a dignified life. This report offers 4,000 l/p/d as a reference for further discussion.**

- New water provision should focus on those left behind first.

3. We must **value water, the Earth's most precious resource, to reflect its scarcity, ensure its efficient and equitable use, and preserve its critical role in sustaining all other natural ecosystems**.

- We must price water properly to incentivise its conservation, particularly by the largest users. Today's massive subsidies that contribute to water's overuse in many sectors and environmental degradation should be redirected towards water-saving solutions, protecting and restoring freshwater ecosystems, and ensuring access to clean water for vulnerable communities.
- We must account for the impacts of industrial, national and global development on both blue and green water resources.
- We must also embed the value of green water systematically in decisions on land use so as to better protect evapotranspiration hotspots such as forests, wetlands, and watersheds. Measuring green water's benefits, including its co-benefits, can also enable schemes for Payment for Ecosystem Services.

4. We must **shape markets to spur a wave of mission-oriented innovations, capacity-building and investments across the entire water cycle**, including blue and green water, to radically transform how water is used, supplied, and conserved. These investments must be **evaluated not in terms of short-run costs and benefits, but for how they can catalyse dynamic, long-run economic and social benefits**.

5. We must **forge partnerships** between all stakeholders, from local to global, **around five missions that address the most important and interconnected challenges of the global water crisis**, and must drive innovation in policies, institutions and technologies:

- **Launch a new revolution in food systems** to improve water productivity in agriculture while meeting the nutritional needs of a growing world population.
- **Conserve and restore natural habitats critical to protect green water.**
- **Establish a circular water economy,** including changes in industrial processes.
- **Enable a clean-energy and AI-rich era with much lower water intensity.**
- **Ensure that no child dies from unsafe water by 2030,** by securing the reliable supply of potable water and sanitation for underserved communities.

6. We must forge **symbiotic partnerships between the public and private sectors to deliver efficient, equitable, and environmentally sustainable use of water from the start**.

- Governments should incorporate conditionalities in contracts and property rights to ensure high standards of water use efficiency and environmental protection, including corporate responsibility for watershed and water basin conservation programmes. They should also provide certainty for investors through clear and consistent regulation and policies, including realistic tariff adjustments.

- For utilities, collaborative decision-making and contract design can steer the private sector toward public value creation with appropriate risk and reward sharing. The focus of partnerships should be on outcome-based performance for operational efficiencies and long-term system resilience.

7. We must **raise the quantity, quality and reliability of finance for water in every sector**.

- **Government budgets themselves must reprioritise investments in water, and repurpose today's environmentally harmful subsidies,** estimated at over US$700 billion per year in agriculture and water and sanitation alone. The discount rates used to assess investments in water infrastructure and ecosystem preservation should take into account their long term - including intergenerational - social, economic and environmental benefits.

- **Development finance institutions (DFIs) – national, regional, and multilateral – must be regeared to provide catalytic finance** to unlock vastly greater amounts of private finance, including more patient finance for water infrastructure projects.

- **Just Water Partnerships involving DFIs and national authorities should be established to build capacity and mobilise investments for low and lower-middle income countries.** There is large untapped potential for doing so, such as by leveraging concessional finance and pooling risk through bundling projects across sectors. Also key in creating an enabling environment for financing is to build a pipeline of bankable projects, consistent with holistic, programmatic approaches and national development strategies.

8. We must **harness data as a foundation for action** by governments, businesses, and communities.

- We should work towards **a new global water data infrastructure, building on and strengthening capacities for data collection on blue and green water at every level of the water cycle**, from local to river basin to global. It should include local and Indigenous knowledge, and aim for interoperability of data reporting.

- We must **accelerate efforts toward market-based disclosure of corporate water footprints, and expedite work towards regulatory standards for mandatory disclosure**, so as to steer action toward sustainable water practices. The aim must be providing transparency on the double materiality of water risks posed by companies' operations – including both their own vulnerabilities, and the impact of their operations on blue and green water resources. We recommend that **water disclosure be integrated in carbon transition plans** and be an integral part of sustainability-related disclosures.

- We must develop pathways to **value water as natural capital to enable responsible stewardship of freshwater ecosystems**, including enabling governments and all stakeholders to evaluate the costs and benefits associated with land use changes.

9. We must build **global water governance that values water as an organising principle, recognises that water is both a local and global issue, and that the hydrological cycle encompassing both blue and green water is a collective and systemic challenge**.

- The **ultimate ambition should be the establishment of a Global Water Pact** that sets clear and measurable goals to stabilise the hydrological cycle and safeguard the world's water resources for a sustainable and just water future.

- To achieve such a Pact, we need a **multi-stakeholder approach that provides for a clear action agenda, institutional innovation, and capacity building**.

- The five critical water missions offer a starting framework for developing public-private-people coalitions, drawing on diverse expertise and engaging with all sectors and voices, including Indigenous Peoples and local communities, women, and youth.

- Water and its values should be anchored in every convention, including climate, biodiversity, wetlands, and desertification, and UN agreement, with clear goals and targets.

[i] This is a rough while extremely conservative threshold for the minimum green water requirement per person, given that it is not possible, in the real world, to achieve 100% transpiration efficiency.

[ii] The redistribution of mass on Earth's surface (such as the movement of water) causes measurable changes in its gravity field. GRACE measures Earth's gravity field, making it possible to estimate the total amount of water stored on and below the surface.

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Chapter 2

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Chapter 6

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The Global Commission on the Economics of Water (GCEW) is redefining the way we value and govern water for the common good.

It is presenting the evidence and the pathways for changes in policy, business approaches and global collaboration to support climate and water justice, sustainability, and food-energy-water security.

The Commission is convened by the Government of the Netherlands and facilitated by the Organisation for Economic Co-operation and Development (OECD). It was launched in May 2022 with a two-year mandate.

The GCEW is executed by an independent and diverse group of eminent policy makers and researchers in fields that bring novel perspectives to water economics, aligning the planetary economy with sustainable water-resource management.

Its purpose is to make a significant and ambitious contribution to the global effort to spur change in the way societies govern, use and value water.

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