

ARTICLE

How Climate Change Impacts Water Access



The water cycle is part of our everyday lives, but climate change may have dire consequences for everyday water access.

GRADES
5 - 8

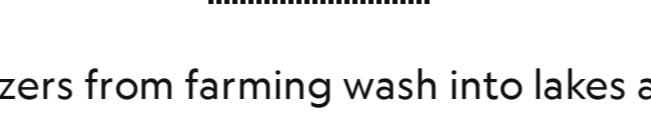
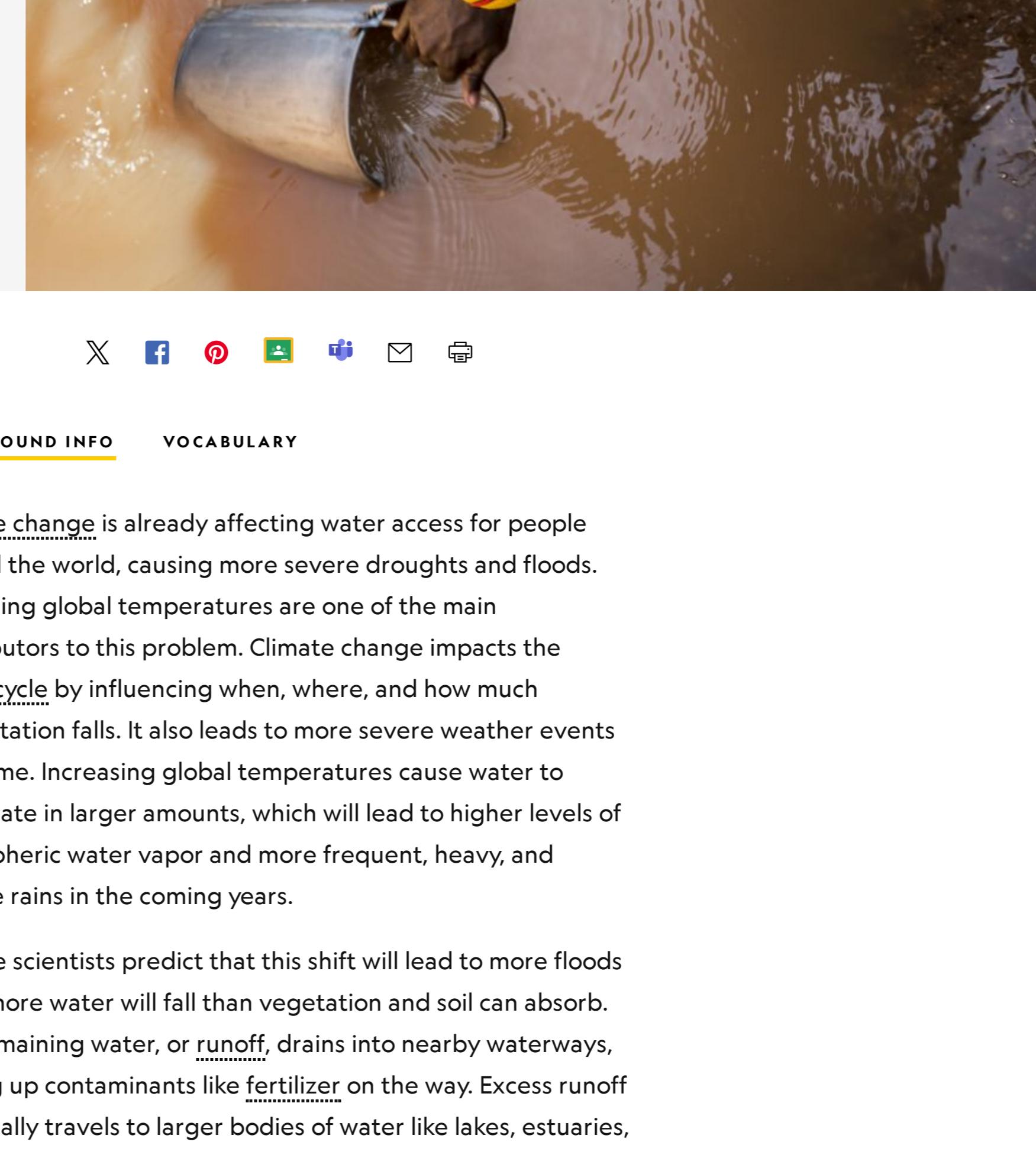
SUBJECTS
Biology, Health, Conservation, Earth Science

IMAGE

Herder Collecting Water

Climate change is already hurting water access for people around the world. Here, a Samburu herder collects water for his flock in Sahara Conservancy, Kenya.

PHOTOGRAPH FROM THE NATIONAL GEOGRAPHIC IMAGE COLLECTION



BACKGROUND INFO

VOCABULARY

Climate change is already affecting water access for people around the world, causing more severe droughts and floods. Increasing global temperatures are one of the main contributors to this problem. Climate change impacts the water cycle by influencing when, where, and how much precipitation falls. It also leads to more severe weather events over time. Increasing global temperatures cause water to evaporate in larger amounts, which will lead to higher levels of atmospheric water vapor and more frequent, heavy, and intense rains in the coming years.

Climate scientists predict that this shift will lead to more floods since more water will fall than vegetation and soil can absorb. The remaining water, or runoff, drains into nearby waterways, picking up contaminants like fertilizer on the way. Excess runoff eventually travels to larger bodies of water like lakes, estuaries, and the ocean, polluting the water supply and limiting water access for humans and ecosystems.

When fertilizers from farming wash into lakes and the ocean, they promote the rapid growth of algae. These resulting algal blooms clog coasts and waterways with clouds of green, blue-green, red, or brown algae. The blooms block sunlight from reaching underwater life and diminish oxygen levels within the water. Toxins from the blooms can kill off fish and other aquatic animals, make people sick, and even kill humans. These toxins are especially dangerous because they can survive purification processes, making tap water unfit to consume once contaminated. Algal blooms also impact industries that rely on the water for business, and often cause local waterfronts to shut down during blooms. As the climate warms, harmful algal blooms happen more often and become more severe.

As the ocean warms, freshwater glaciers around Earth begin to melt at an unsustainable rate, which results in rising sea levels. The freshwater from the melted glaciers eventually runs into the ocean. With the rising of sea levels, salt water can more easily contaminate underground freshwater-bearing rocks, called aquifers. A process called desalination removes salt from salt water, but it is a last-resort, energy-intensive, costly process for places where there are persistent droughts and freshwater is lacking. The Middle East, North Africa, and the Caribbean use desalination to produce freshwater out of necessity.

In the Northern Hemisphere—where snow, a freshwater source, typically accumulates—warmer temperatures mean less snowfall, which leaves less water available in local reservoirs after winter. This negatively impacts farmers, who are left without enough water to irrigate their crops in the growing season.

There are many things that everyone can do to lessen the impact of climate change. Some measures include growing your own fruits and vegetables or buying locally grown produce, since produce is often transported to grocery stores from far away by trucks, which add more carbon dioxide to the atmosphere. You could also walk or ride a bike instead of driving a car. On a larger scale, industries that are dependent on fossil fuels need to make the switch to renewable, cleaner energy sources to influence our planet for the better.

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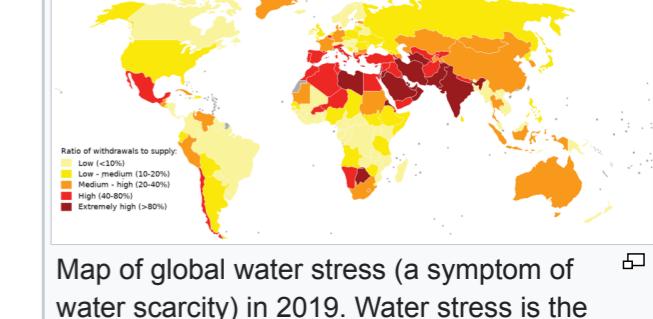


Water scarcity

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Water scarcity (closely related to [water stress](#) or [water crisis](#)) is the lack of [fresh water resources](#) to meet the standard water demand. There are two types of water scarcity. One is [physical](#). The other is [economic water scarcity](#).^{[2]:560} Physical water scarcity is where there is not enough water to meet all demands. This includes water needed for [ecosystems](#) to function. Regions with a [desert climate](#) often face physical water scarcity.^[3] [Central Asia](#), [West Asia](#), and [North Africa](#) are examples of arid areas. Economic water scarcity results from a lack of investment in infrastructure or technology to draw water from rivers, [aquifers](#), or other water sources. It also results from weak human capacity to meet water demand.^{[2]:560} Many people in [Sub-Saharan Africa](#) are living with economic water scarcity.^{[4]:11}



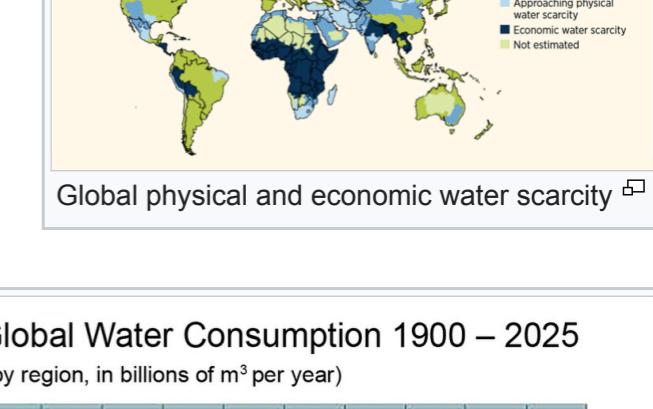
There is enough freshwater available globally and averaged over the year to meet demand. As such, water scarcity is caused by a mismatch between when and where people need water, and when and where it is available.^[5] This can happen due to an [increase in the number of people](#) in a region, changing living conditions and diets, and expansion of [irrigated agriculture](#).^{[6][7][8]} Climate change (including [droughts](#) or [floods](#)), [deforestation](#), [water pollution](#) and wasteful use of water can also mean there is not enough water.^[9] These variations in scarcity may also be a function of prevailing [economic policy](#) and planning approaches.

Water scarcity assessments look at many types of information. They include green water ([soil moisture](#)), [water quality](#), environmental flow requirements, and [virtual water trade](#).^[8] Water stress is one parameter to measure water scarcity. It is useful in the context of [Sustainable Development Goal 6](#).^[10] Half a billion people live in areas with severe water scarcity throughout the year,^{[5][8]} and around four billion people face severe water scarcity at least one month per year.^{[5][11]} Half of the world's [largest cities](#) experience water scarcity.^[11] There are 2.3 billion people who reside in nations with water scarcities (meaning less than 1700 m³ of water per person per year).^{[12][13][14]}

There are different ways to reduce water scarcity. It can be done through supply and demand side management, cooperation between countries and [water conservation](#). Expanding sources of usable water can help. [Reusing wastewater](#) and [desalination](#) are ways to do this. Others are reducing [water pollution](#) and changes to the virtual water trade.

Definitions [\[edit\]](#)

[Water scarcity](#) has been defined as the "volumetric abundance, or lack thereof, of [freshwater resources](#)" and it is thought to be "human-driven".^{[15]:4} This can also be called "physical water scarcity".^[4] There are two types of water scarcity. One is [physical water scarcity](#) and the other is [economic water scarcity](#).^{[2]:560} Some definitions of water scarcity look at environmental water requirements. This approach varies from one organization to another.^{[15]:4}

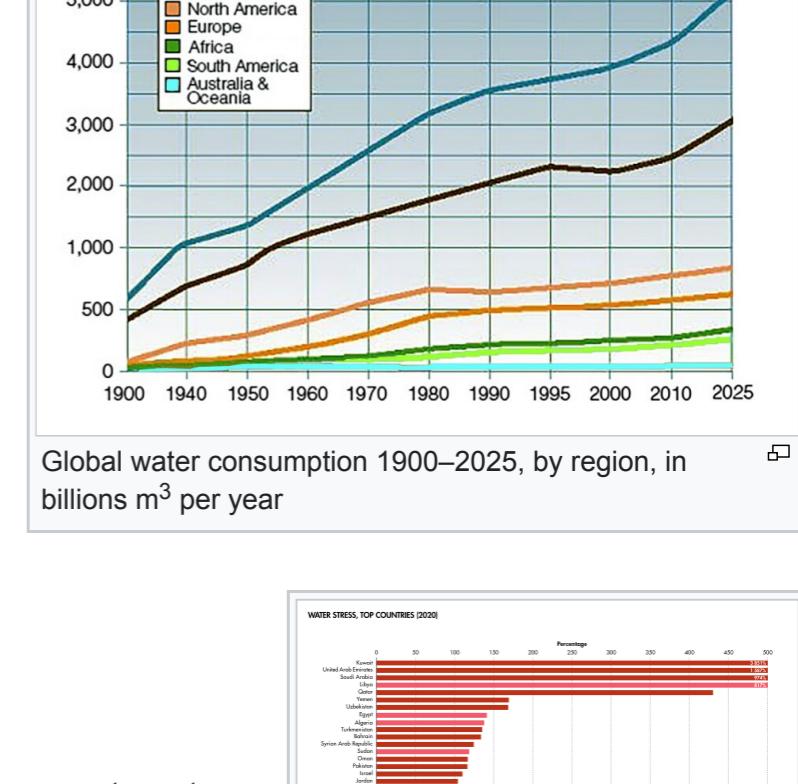


Related concepts are [water stress](#) and [water risk](#). The CEO Water Mandate, an initiative of the [UN Global Compact](#), proposed to harmonize these in 2014.^{[15]:2} In their discussion paper they state that these three terms should not be used interchangeably.^{[15]:3}

Some organizations define [water stress](#) as a broader concept. It would include aspects of water availability, [water quality](#) and accessibility. Accessibility depends on existing infrastructure. It also depends on whether customers can afford to pay for the water.^{[15]:4} Some experts call this [economic water scarcity](#).^[4]

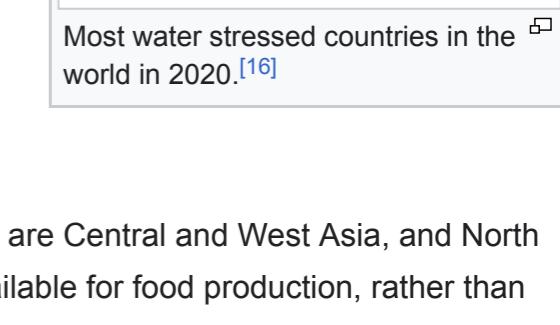
The [FAO](#) defines [water stress](#) as the "symptoms of water scarcity or shortage". Such symptoms could be "growing conflict between users, and competition for water, declining standards of reliability and service, harvest failures and food insecurity".^{[17]:6} This is measured with a range of Water Stress Indices.

A group of scientists provided another definition for water stress in 2016: "Water stress refers to the impact of high water use (either withdrawals or consumption) relative to water availability."^[1] This means [water stress](#) would be a *demand-driven scarcity*.



Types [\[edit\]](#)

Experts have defined two types of water scarcity. One is [physical water scarcity](#). The other is [economic water scarcity](#). These terms were first defined in a 2007 study led by the [International Water Management Institute](#). This examined the use of water in [agriculture](#) over the previous 50 years. It aimed to find out if the world had sufficient water resources to produce food for the growing population in the future.^{[4][17]:1}



Physical water scarcity [\[edit\]](#)

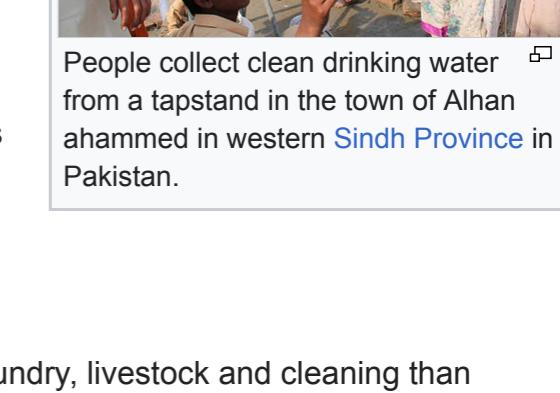
Physical water scarcity occurs when natural water resources are not enough to meet all demands. This includes water needed for ecosystems to function well. Dry regions often suffer from physical water scarcity. Human influence on climate has intensified water scarcity in areas where it was already a problem.^[18] It also occurs where water seems abundant but where resources are over-committed. One example is overdevelopment of [hydraulic infrastructure](#). This can be for [irrigation](#) or [energy generation](#). There are several symptoms of physical water scarcity. They include severe [environmental degradation](#), declining [groundwater](#) and water allocations favouring some groups over others.^{[17]:6}

Water is scarce in densely populated [arid areas](#). These are projected to have less than 1000 cubic meters available per capita per year. Examples are Central and West Asia, and North Africa).^[3] A study in 2007 found that more than 1.2 billion people live in areas of physical water scarcity.^[19] This water scarcity relates to water available for food production, rather than for [drinking water](#) which is a much smaller amount.^{[3][20]}

Some academics propose a separate type of water scarcity termed [ecological water scarcity](#).^[21] though some publications argue that this falls within the definition of physical water scarcity.^{[17][4]} It would focus on the water demand of ecosystems, referring to the minimum quantity and quality of water discharge needed to maintain sustainable and functional ecosystems. Results from a modelling study in 2022 show that northern China suffered more severe ecological water scarcity than southern China. The driving factor of ecological water scarcity in most provinces was water pollution rather than human water use.^[21]

Economic water scarcity [\[edit\]](#)

Economic water scarcity is due to a lack of investment in infrastructure or technology to draw water from rivers, aquifers, or other water sources. It also reflects insufficient human capacity to meet the demand for water.^{[22]:560} It causes people without reliable water access to travel long distances to fetch water for household and agricultural uses. Such water is often unclean.



The [United Nations Development Programme](#) says economic water scarcity is the most common cause of water scarcity. This is because most countries or regions have enough water to meet household, industrial, agricultural, and environmental needs. But they lack the means to provide it in an accessible manner.^[23] Around a fifth of the world's population currently live in regions affected by physical water scarcity.^[23]

A quarter of the world's population is affected by economic water scarcity. It is a feature of much of Sub-Saharan Africa.^{[4]:11} So better water infrastructure there could help to reduce [poverty](#). Investing in water retention and irrigation infrastructure would help increase food production. This is especially the case for developing countries that rely on low-yield agriculture.^[24] Providing water that is adequate for consumption would also benefit public health.^[25] This is not only a question of new infrastructure. Economic and political intervention are necessary to tackle poverty and social inequality. The lack of funding means there is a need for planning.^[26]

The emphasis is usually on improving water sources for [drinking](#) and domestic purposes. But more water is used for purposes such as bathing, laundry, livestock and cleaning than drinking and cooking.^[25] This suggests that too much emphasis on drinking water addresses only part of the problem. So it can limit the range of solutions available.^[25]

Challenges [\[edit\]](#)

Simple indicators [\[edit\]](#)

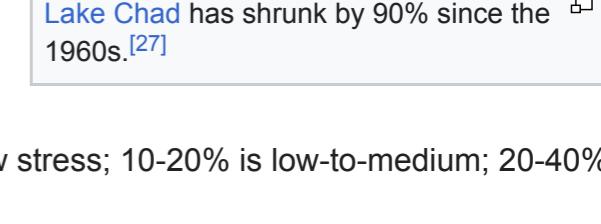
There are several indicators for measuring water scarcity. One is the water use to availability ratio. This is also known as the criticality ratio.

Another is the IWMI Indicator. This measures physical and economic water scarcity. Another is the water poverty index.^[8]

"Water stress" is a criterion to measure water scarcity. Experts use it in the context of [Sustainable Development Goal 6](#).^[10] A report by the FAO in 2018 provided a definition of water stress. It described it as "the ratio between total freshwater withdrawn (TWW) by all major sectors and total renewable freshwater resources (TRWR), after taking into account [environmental flow](#) requirements (EFR)". This means that the value for TWW is divided by the difference between TRWR minus EFR.^{[28]:xii} Environmental flows are water flows required to sustain

[freshwater](#) and [estuarine ecosystems](#). A previous definition in [Millennium Development Goal](#) 7, target 7.A, was simply the proportion of total water resources used, without taking EFR into consideration.^{[28]:28} This definition sets out several categories for water stress. Below 10% is low stress; 10-20% is low-to-medium; 20-40% medium-to-high; 40-80% high; above 80% very high.^[29]

Indicators are used to measure the extent of water scarcity.^[30] One way to measure water scarcity is to calculate the amount of water resources available per person each year. One example is the "Falkenmark Water Stress Indicator". This was developed by [Malin Falkenmark](#). This indicator says a country or region experiences "water stress" when annual water supplies drop below 1,700 cubic meters per person per year.^[31] Levels between 1,700 and 1,000 cubic meters will lead to periodic or limited water shortages. When water supplies drop below 1,000 cubic meters per person per year the country faces "water scarcity". However, the Falkenmark Water Stress Indicator does not help to explain the true nature of water scarcity.^[3]



Lake Chad has shrunk by 90% since the 1960s.^[27]

It is also possible to measure water scarcity by looking at [renewable freshwater](#). Experts use it when evaluating water scarcity. This metric can describe the total available water resources each country contains. This total available water resource gives an idea of whether a country tends to experience physical water scarcity.^[32] This metric has a drawback because it is an average. Precipitation delivers water unevenly across the planet each year. So annual renewable water resources vary from year to year. This metric does not describe how easy it is for individuals, households, industries or government to access water. Lastly this metric gives a description of a whole country. So it does not accurately portray whether a country is experiencing water scarcity. For example, Canada and Brazil both have very high levels of available water supply. But they still face various water-related problems.^[32] Some tropical countries in Asia and Africa have low levels of freshwater resources.

More sophisticated indicators [edit]

Water scarcity assessments must include several types of information. They include data on green water ([soil moisture](#)), [water quality](#), environmental flow requirements, globalisation, and [virtual water trade](#).^[8] Since the early 2000s, water scarcity assessments have used more complex models. These benefit from spatial analysis tools. Green-blue water scarcity is one of these. Footprint-based water scarcity assessment is another. Another is cumulative abstraction to demand ratio, which considers temporal variations. Further examples are [LCA](#)-based water stress indicators and integrated water quantity-quality environment flow.^[8] Since the early 2010s assessments have looked at water scarcity from both quantity and quality perspectives.^[33]

A successful assessment will bring together experts from several scientific disciplines. These include the hydrological, water quality, [aquatic ecosystem](#) science, and social science communities.^[8]

Available water [edit]

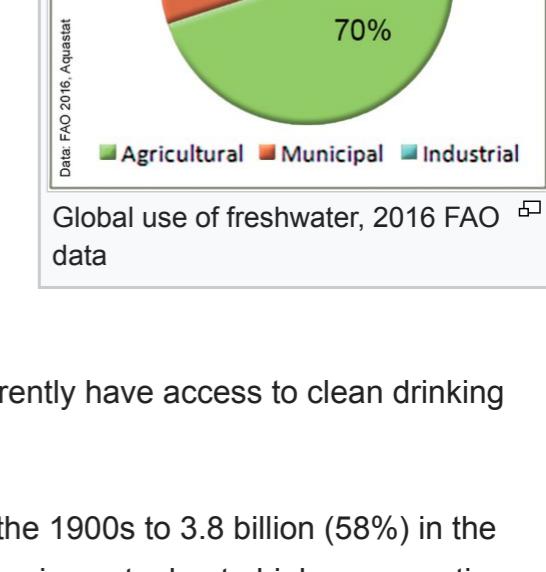
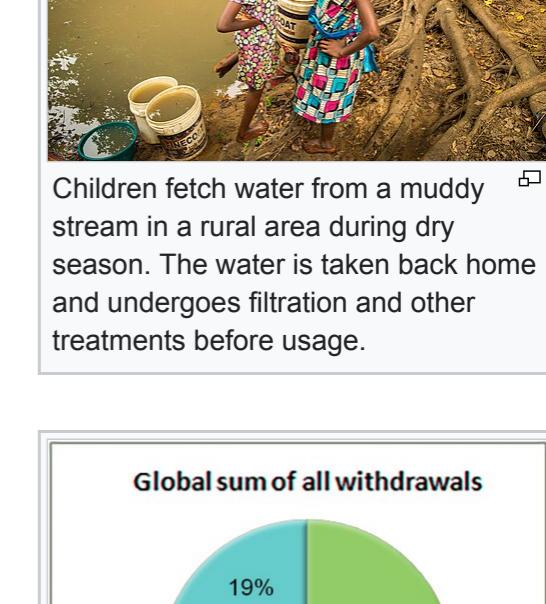
The [United Nations](#) estimates that only 200,000 cubic kilometers of the total 1.4 billion cubic kilometers of water on Earth is freshwater available for human consumption. A mere 0.014% of all [water on Earth](#) is both fresh and easily [accessible](#).^[34] Of the remaining water, 97% is saline, and a little less than 3% is difficult to access. The fresh water available to us on the planet is around 1% of the total water on earth.^[35] The total amount of easily accessible freshwater on Earth is 14,000 cubic kilometers. This takes the form of [surface water](#) such as rivers and lakes or [groundwater](#), for example in [aquifers](#). Of this total amount, humanity uses and resuses just 5,000 cubic kilometers. Technically, there is a sufficient amount of freshwater on a global scale. So in theory there is more than enough freshwater available to meet the demands of the current world population of 8 billion people. There is even enough to support [population growth](#) to 9 billion or more. But unequal geographical distribution and unequal consumption of water makes it a scarce resource in some regions and groups of people.

Rivers and lakes provide common surface sources of freshwater. But other water resources such as groundwater and glaciers have become more developed sources of freshwater. They have become the main source of clean water. Groundwater is water that has pooled below the surface of the Earth. It can provide a usable quantity of water through springs or wells. These areas of groundwater are also known as aquifers. It is becoming harder to use conventional sources because of pollution and climate change. So people are drawing more and more on these other sources. Population growth is encouraging greater use of these types of water resources.^[32]

Scale [edit]

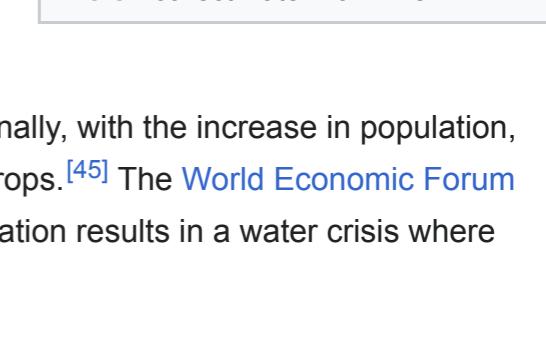
Current estimates [edit]

In 2019 the [World Economic Forum](#) listed water scarcity as one of the largest [global risks](#) in terms of potential impact over the next decade.^[36] Water scarcity can take several forms. One is a failure to meet demand for water, partially or totally. Other examples are economic competition for water quantity or quality, disputes between users, irreversible depletion of [groundwater](#), and negative impacts on the [environment](#).



Future predictions [edit]

In the 20th century, water use has been growing at more than twice the rate of the population increase. Specifically, water withdrawals are likely to rise by 50 percent by 2025 in developing countries, and 18 per cent in developed countries.^[40] One continent, for example, [Africa](#), has been predicted to have 75 to 250 million inhabitants lacking access to fresh water.^[41] By 2025, 1.8 billion people will be living in countries or regions with absolute water scarcity, and two-thirds of the world population could be under stress conditions.^[42] By 2050, more than half of the world's population will live in water-stressed areas, and another billion may lack sufficient water, MIT researchers find.^[43]



With the increase in global temperatures and an increase in water demand, six out of ten people are at risk of being water-stressed. The drying out of wetlands globally, at around 67%, was a direct cause of a large number of people at risk of water stress. As global demand for water increases and temperatures rise, it is likely that two thirds of the population will live under water stress in 2025.^{[44][35]:191}

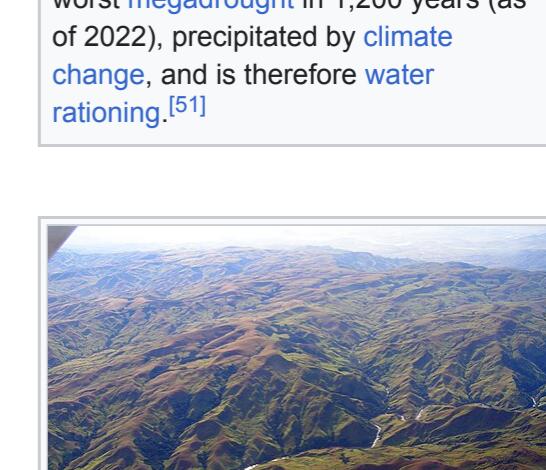
According to a projection by the United Nations, by 2040, there can be about 4.5 billion people affected by a water crisis (or water scarcity). Additionally, with the increase in population, there will be a demand for food, and for the food output to match the population growth, there would be an increased demand for water to irrigate crops.^[45] The [World Economic Forum](#) estimates that global water demand will surpass global supply by 40% by 2030.^{[46][47]} Increasing the water demand as well as increasing the population results in a water crisis where there is not enough water to share in healthy levels. The crises are not only due to quantity but quality also matters.

A study found that 6-20% of about 39 million [groundwater wells](#) are at high risk of running dry if local groundwater levels decline by a few meters. In many areas and with possibly more than half of major [aquifers](#)^[48] this would apply if they simply continue to decline.^{[49][50]}

Impacts [edit]

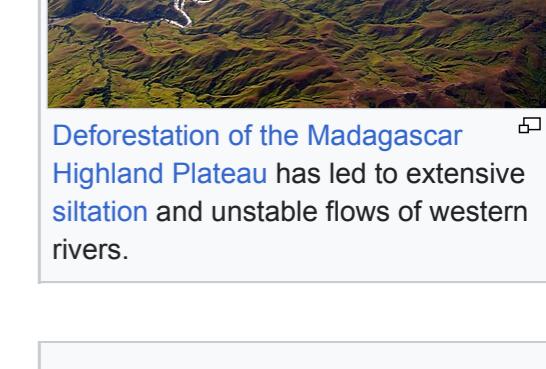
Water supply shortages [edit]

Controllable factors such as the management and distribution of the water supply can contribute to scarcity. A 2006 United Nations report focuses on issues of governance as the core of the water crisis. The report noted that: "There is enough water for everyone". It also said: "Water insufficiency is often due to mismanagement, corruption, lack of appropriate institutions, bureaucratic inertia and a shortage of investment in both human capacity and physical infrastructure".^[52]



Economists and others have argued that a lack of [property rights](#), government regulations and water subsidies have given rise to the situation with water. These factors cause prices to be too low and consumption too high, making a point for [water privatization](#).^{[53][54][55]}

The clean water crisis is an emerging global crisis affecting approximately 785 million people around the world.^[56] 1.1 billion people lack access to water and 2.7 billion experience water scarcity at least one month in a year. 2.4 billion people suffer from contaminated water and poor sanitation. Contamination of water can lead to deadly [diarrheal diseases](#) such as [cholera](#) and [typhoid fever](#) and other [waterborne diseases](#). These account for 80% of illnesses around the world.^[57]



Through the last hundred years, more than half of the Earth's wetlands have been destroyed and have disappeared.^[9] These wetlands are important as the habitats of numerous creatures such as mammals, birds, fish, amphibians, and [invertebrates](#). They also support the growing of rice and other food crops. And they provide [water filtration](#) and protection from storms and flooding. Freshwater lakes such as the [Aral Sea](#) in central Asia have also suffered. It was once the fourth largest freshwater lake in the world. But it has lost more than 58,000 square km of area and vastly increased in salt concentration over the span of three decades.^[9]

[Subsidence](#) is another result of water scarcity. The [U.S. Geological Survey](#) estimates that subsidence has affected more than 17,000 square miles in 45 U.S. states, 80 percent of it due to groundwater usage.^[60]

Vegetation and wildlife need sufficient freshwater. [Marshes](#), [bogs](#) and [riparian zones](#) are more clearly dependent upon sustainable water supply. Forests and other upland ecosystems are equally at risk as water becomes less available. In the case of wetlands, a lot of ground has been

simply taken from wildlife use to feed and house the expanding human population. Other areas have also suffered from a gradual fall in freshwater inflow as upstream water is diverted for human use.



An abandoned ship in the former Aral Sea, near Aral, Kazakhstan

Potential for conflict [edit]

Other impacts include growing conflict between users and growing competition for water.^{[17]:6} Examples for the potential for conflict from water scarcity include: Food insecurity in the Middle East and North Africa Region^[61] and regional conflicts over scarce water resources.^[62]

Causes and contributing factors [edit]

Population growth [edit]

Main article: [Population growth](#)

Around fifty years ago, the common view was that water was an infinite resource. At that time, there were fewer than half the current number of people on the planet. People were not as wealthy as today, consumed fewer calories and ate less meat, so less water was needed to produce their food. They required a third of the volume of water we presently take from rivers. Today, the competition for water resources is much more intense. This is because there are now seven billion people on the planet and their consumption of water-thirsty meat is rising. And [industry](#), [urbanization](#), biofuel crops, and water reliant food items are competing more and more for water. In the future, even more water will be needed to produce food because the Earth's population is forecast to rise to 9 billion by 2050.^[63]

In 2000, the world population was 6.2 billion. The UN estimates that by 2050 there will be an additional 3.5 billion people, with most of the growth in [developing countries](#) that already suffer water stress.^[64] This will increase demand for water unless there are corresponding increases in [water conservation](#) and [recycling](#).^[65] In building on the data presented here by the UN, the [World Bank](#)^[66] goes on to explain that access to water for producing food will be one of the main challenges in the decades to come. It will be necessary to balance access to water with managing water in a sustainable way. At the same time it will be necessary to take the [impact of climate change](#) and other environmental and social variables into account.^[67]

In 60% of European cities with more than 100,000 people, groundwater is being used at a faster rate than it can be replenished.^[68]

Over-exploitation of groundwater [edit]

Main article: [Groundwater](#)

The [increase in the number of people](#) is increasing competition for water. This is depleting many of the world's major aquifers. It has two causes. One is direct human consumption. The other is agricultural irrigation. Millions of [pumps](#) of all sizes are currently extracting groundwater throughout the world. Irrigation in dry areas such as northern [China](#), [Nepal](#) and [India](#) draws on groundwater. And it is extracting groundwater at an unsustainable rate. Many cities have experienced aquifer drops of between 10 and 50 meters. They include [Mexico City](#), [Bangkok](#), [Beijing](#), [Chennai](#) and [Shanghai](#).^[70]



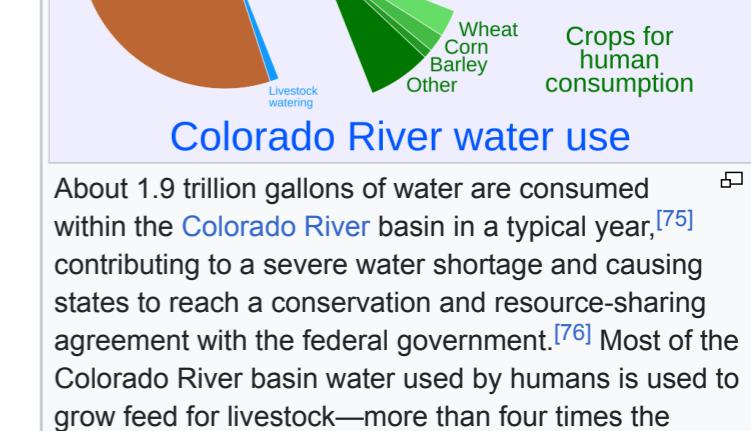
Pivot irrigation in Saudi Arabia, April 1997. Saudi Arabia is suffering from a major depletion of the water in its underground aquifers.^[69]

Until recently, groundwater was not a highly used resource. In the 1960s, more and more groundwater aquifers developed.^[71] Improved knowledge, technology and funding have made it possible to focus more on drawing water from groundwater resources instead of surface water. These made the agricultural groundwater revolution possible. They expanded the irrigation sector which made it possible to increase food production and development in rural areas.^[72] Groundwater supplies nearly half of all drinking water in the world.^[73] The large volumes of water stored underground in most aquifers have a considerable buffer capacity. This makes it possible to withdraw water during periods of drought or little rainfall.^[32] This is crucial for people that live in regions that cannot depend on [precipitation](#) or surface water for their only supplies. It provides reliable access to water all year round. As of 2010, the world's aggregated groundwater abstraction is estimated at 1,000 km³ per year. Of this 67% goes on irrigation, 22% on domestic purposes and 11% on industrial purposes.^[32] The top ten major consumers of abstracted water make up 72% of all abstracted water use worldwide. They are India, China, United States of America, Pakistan, Iran, Bangladesh, Mexico, Saudi Arabia, Indonesia, and Italy.^[32]

Groundwater sources are quite plentiful. But one major area of concern is the renewal or recharge rate of some groundwater sources. [Extracting](#) from non-renewable groundwater sources could exhaust them if they are not properly monitored and managed.^[74] Increasing use of groundwater can also reduce water quality over time. Groundwater systems often show falls in natural outflows, stored volumes, and water levels as well as water degradation.^[32] Groundwater depletion can cause harm in many ways. These include more costly groundwater pumping and changes in salinity and other types of water quality. They can also lead to land subsidence, degraded springs and reduced baseflows.

Expansion of agricultural and industrial users [edit]

The main cause of water scarcity as a result of consumption is the extensive use of water in [agriculture/livestock breeding](#) and [industry](#). People in developed countries generally use about 10 times more water a day than people in [developing countries](#).^[75] A large part of this is [indirect use](#) in water-intensive agricultural and industrial production of [consumer goods](#). Examples are fruit, oilseed crops and cotton. Many of these production chains are globalized, So a lot of water consumption and pollution in developing countries occurs to produce goods for consumption in developed countries.^[78]



About 1.9 trillion gallons of water are consumed within the Colorado River basin in a typical year,^[75] contributing to a severe water shortage and causing states to reach a conservation and resource-sharing agreement with the federal government.^[76] Most of the Colorado River basin water used by humans is used to grow feed for livestock—more than four times the amount used for crops for direct human consumption.^[75]

Many aquifers have been over-pumped and are not recharging quickly. This does not use up the total fresh water supply. But it means that much has become polluted, salted, unsuitable or otherwise unavailable for drinking, industry and agriculture. To avoid a global water crisis, farmers will have to increase productivity to meet growing demands for food. At the same time industry and cities find will have to find ways to use water more efficiently.^[79]

Business activities such as tourism are continuing to expand. They create a need for increases in water [supply](#) and [sanitation](#). This in turn can lead to more pressure on water resources and natural [ecosystems](#). The approximate 50% growth in world energy use by 2040 will also increase the need for efficient water use.^[79] It may mean some water use shifts from irrigation to industry. This is because thermal power generation uses water for steam generation and cooling.^[80]

Water pollution [edit]

This section is an excerpt from [Water pollution](#). [edit]

[Water pollution](#) (or aquatic pollution) is the contamination of [water bodies](#), with a negative impact on their uses.^{[81]:6} It is usually a result of human activities. Water bodies include [lakes](#), [rivers](#), [oceans](#), [aquifers](#), [reservoirs](#) and [groundwater](#). Water pollution results when [contaminants](#) mix with these water bodies. Contaminants can come from one of four main sources. These are [sewage](#) discharges, industrial activities, agricultural activities, and urban runoff including [stormwater](#).^[82] Water pollution may affect either [surface water](#) or [groundwater](#). This form of pollution can lead to many problems. One is the [degradation](#) of [aquatic ecosystems](#). Another is spreading [water-borne diseases](#) when people use polluted water for drinking or irrigation.^[83] Water pollution also reduces the [ecosystem services](#) such as [drinking water](#) provided by the [water resource](#).

Sources of water pollution are either [point sources](#) or [non-point sources](#).^[84] Point sources have one identifiable cause, such as a [storm drain](#), a [wastewater treatment plant](#), or an [oil spill](#). Non-point sources are more diffuse. An example is [agricultural runoff](#).^[85] Pollution is the result of the cumulative effect over time. Pollution may take many forms. One would be toxic substances such as oil, metals, plastics, [pesticides](#), [persistent organic pollutants](#), and industrial waste products. Another is stressful conditions such as changes of [pH](#), [hypoxia](#) or anoxia, increased temperatures, excessive [turbidity](#), or changes of [salinity](#)). The introduction of [pathogenic organisms](#) is another. Contaminants may include [organic](#) and [inorganic](#) substances. A common cause of [thermal pollution](#) is the use of water as a [coolant](#) by [power plants](#) and industrial manufacturers.

Climate change [edit]

Further information: [Effects of climate change on the water cycle](#) and [Water security § Climate change](#)

Climate change could have a big impact on water resources around the world because of the close connections between the climate and [hydrological cycle](#). Rising temperatures will increase [evaporation](#) and lead to increases in precipitation. However there will be regional variations in [rainfall](#). Both [droughts](#) and [floods](#) may become more frequent and more severe in different regions at different times. There will be generally less snowfall and more rainfall in a warmer climate.^[86] Changes in [snowfall](#) and [snow melt](#) in mountainous areas will also take place. Higher temperatures will also affect water quality in ways that scientists do not fully understand. Possible impacts include increased [eutrophication](#). Climate change could also boost demand for irrigation systems in agriculture. There is now ample evidence that greater hydrologic variability and climate change have had a profound impact on the water sector, and will continue to do so. This will show up in the hydrologic cycle, water availability, water demand, and water allocation at the global, regional, basin, and local levels.^[87]

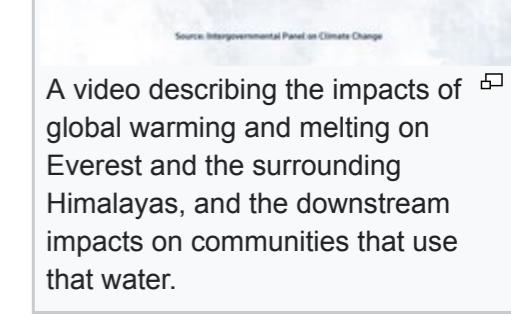
The United Nations' [FAO](#) states that by 2025 1.9 billion people will live in countries or regions with absolute water scarcity. It says two thirds of the world's population could be under stress conditions.^[88] The World Bank says that climate change could profoundly alter future patterns of water availability and use. This will make water stress and insecurity worse, at the global level and in sectors that depend on water.^[89]

Scientists have found that population change is four times more important than long-term climate change in its effects on water scarcity.^[44]

Retreat of mountain glaciers [edit]

This section is an excerpt from [Retreat of glaciers since 1850 § Water supply](#). [edit]

The continued retreat of glaciers will have a number of different quantitative effects. In areas that are heavily dependent on water runoff from glaciers that melt during the warmer summer months, a continuation of the current retreat will eventually deplete the glacial ice and substantially reduce or eliminate runoff. A reduction in runoff will affect the ability to [irrigate](#) crops and will reduce summer stream flows necessary to keep dams and reservoirs replenished. This situation is particularly acute for irrigation in South America, where numerous artificial lakes are filled almost exclusively by glacial melt.^[90] Central Asian countries have also been historically dependent on the seasonal glacier melt water for irrigation and drinking supplies. In Norway, the Alps, and the [Pacific Northwest](#) of North America, glacier runoff is important for [hydropower](#).



Options for improvements [edit]

Supply and demand side management [edit]

Main articles: [Water resource management](#) and [Integrated water resources management](#)

A review in 2006 stated that "It is surprisingly difficult to determine whether water is truly scarce in the physical sense at a global scale (a supply problem) or whether it is available but should be used better (a demand problem)".^[95]

The International Resource Panel of the UN states that governments have invested heavily in inefficient solutions. These are mega-projects like [dams](#), canals, [aqueducts](#), pipelines and water reservoirs. They are generally neither environmentally sustainable nor economically viable.^[96] According to the panel, the most [cost-effective](#) way of decoupling water use from economic growth is for [governments](#) to create [holistic water management plans](#). These would take into account the entire water cycle: from source to distribution, economic use, [treatment](#), [recycling](#), reuse and return to the environment.

In general, there is enough water on an annual and global scale. The issue is more of variation of supply by time and by region. Reservoirs and pipelines would deal with this variable water supply. Well-planned infrastructure with demand side management is necessary. Both supply-side and demand-side management have advantages and disadvantages.^[citation needed]

Co-operation between countries [edit]

Further information: [Water conflict](#) and [International waters](#)

Lack of cooperation may give rise to regional [water conflicts](#). This is especially the case in [developing countries](#). The main reason is disputes regarding the availability, use and management of water.^[62] One example is the dispute between [Egypt](#) and [Ethiopia](#) over the [Grand Ethiopian Renaissance Dam](#) which escalated in 2020.^{[97][98]} Egypt sees the dam as an existential threat, fearing that the dam will reduce the amount of water it receives from the [Nile](#).^[99]

Water conservation [edit]

This section is an excerpt from [Water conservation](#). [edit]

Water conservation aims to [sustainably](#) manage the [natural resource](#) of [fresh water](#), protect the [hydrosphere](#), and meet current and future human [demand](#). Water conservation makes it possible to avoid water scarcity. It covers all the policies, strategies and activities to reach these aims. Population, household size and growth and affluence all affect how much water is used.

Although the terms "water efficiency" and "water conservation" are used interchangeably they are not the same. Water efficiency is a term that refers to the improvements such as the new technology that help with the efficiency and reduction of using water. On the other hand, water conservation is the term for the action of conserving water. In short, water efficiency relates to the development and innovations which help use water more efficiently and water conservation is the act of saving or preserving water.^[100]



United States 1960 postal stamp advocating water conservation

Expanding sources of usable water [edit]

This section is an excerpt from [Water resources § Artificial sources of usable water](#). [edit]

There are several artificial sources of fresh water. One is [treated wastewater \(reclaimed water\)](#). Another is [atmospheric water generators](#).^{[101][102][103]} Desalinated seawater is another important source. It is important to consider the economic and environmental side effects of these technologies.^[104]

Wastewater treatment and reclaimed water [edit]

This section is an excerpt from [Reclaimed water](#). [edit]

Water [reclamation](#) is the process of converting [municipal wastewater](#) or sewage and [industrial wastewater](#) into water that can be [reused](#) for a variety of purposes. It is also called wastewater reuse, water reuse or water recycling. There are many types of reuse. It is possible to reuse water in this way in cities or for irrigation in agriculture. Other types of reuse are environmental reuse, industrial reuse, and reuse for drinking water, whether planned or not. Reuse may include [irrigation](#) of gardens and agricultural fields or replenishing [surface water](#) and [groundwater](#). This latter is also known as [groundwater recharge](#). Reused water also serve various needs in residences such as [toilet flushing](#), businesses, and industry. It is possible to treat wastewater to reach [drinking water](#) standards. Injecting reclaimed water into the water supply distribution system is known as direct potable reuse. Drinking reclaimed water is not typical.^[105] Reusing treated municipal wastewater for irrigation is a long-established practice. This is especially so in [arid](#) countries. Reusing wastewater as part of sustainable [water management](#) allows water to remain an alternative water source for human activities. This can reduce scarcity. It also eases pressures on groundwater and other natural water bodies.^[106]

This section is an excerpt from [Wastewater treatment](#). [edit]

Wastewater treatment is a process which removes and eliminates [contaminants](#) from [wastewater](#). It thus converts it into an [effluent](#) that can be returned to the [water cycle](#). Once back in the water cycle, the effluent creates an acceptable impact on the environment. It is also possible to reuse it. This process is called [water reclamation](#).^[107] The treatment process takes place in a wastewater treatment plant. There are several kinds of wastewater which are treated at the appropriate type of wastewater treatment plant. For domestic wastewater the treatment plant is called a [Sewage Treatment](#). Municipal wastewater or [sewage](#) are other names for [domestic wastewater](#). For industrial wastewater, treatment takes place in a separate [Industrial wastewater treatment](#), or in a sewage treatment plant. In the latter case it usually follows pre-treatment. Further types of wastewater treatment plants include [Agricultural wastewater treatment](#) and [leachate](#) treatment plants.

One common process in wastewater treatment is [phase separation](#), such as sedimentation. Biological and chemical processes such as oxidation are another example. Polishing is also an example. The main by-product from wastewater treatment plants is a type of sludge that is usually treated in the same or another wastewater treatment plant.^{[108]:Ch.14} [Biogas](#) can be another by-product if the process uses anaerobic treatment. Treated wastewater can be reused as [reclaimed water](#).^[109] The main purpose of wastewater treatment is for the treated wastewater to be able to be disposed or reused safely. However, before it is treated, the options for disposal or reuse must be considered so the correct treatment process is used on the wastewater.

Desalination [edit]

This section is an excerpt from [Desalination](#). [edit]

Desalination is a process that removes mineral components from [saline water](#). More generally, desalination is the removal of salts and minerals from a substance.^[110] One example is [soil desalination](#). This is important for agriculture. It is possible to desalinate saltwater, especially [sea water](#), to produce water for human consumption or irrigation. The by-product of the desalination process is [brine](#).^[111] Many seagoing ships and [submarines](#) use desalination. Modern interest in desalination mostly focuses on cost-effective provision of [fresh water](#) for human use. Along with recycled [wastewater](#), it is one of the few [water resources](#) independent of rainfall.^[112]

Virtual water trade [edit]

This section is an excerpt from [Virtual water](#). [edit]

The [virtual water trade](#) is the hidden flow of water in food or other [commodities](#) that are [traded](#) from one place to another.^[113] Other terms for it are embedded or embodied water. The virtual water trade is the idea that virtual water is exchanged along with goods and services. This idea provides a new, amplified perspective on water problems. It balances different perspectives, basic conditions, and interests. This concept makes it possible to distinguish between global, regional, and local levels and their linkages. However, the use of virtual water estimates may offer no guidance for policymakers seeking to ensure they are meeting environmental objectives.

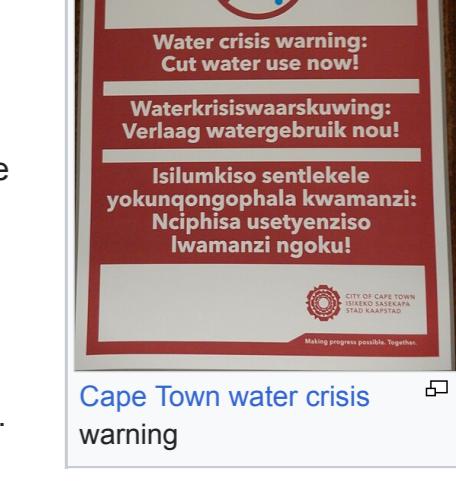
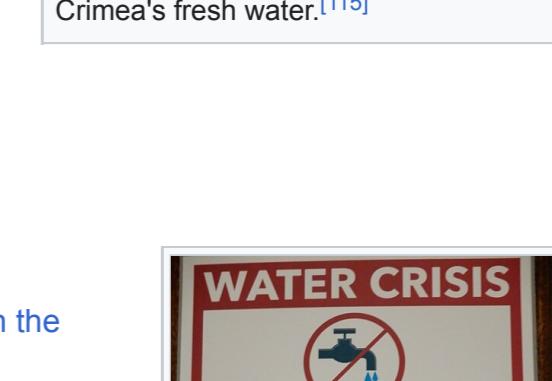
For example, [cereal grains](#) have been major carriers of virtual water in countries where water resources are scarce. So cereal imports can compensate for local water deficits.^[114] However, [low-income countries](#) may not be able to afford such imports in the future. This could lead to [food insecurity](#) and [starvation](#).

Regional examples [edit]

Overview of regions [edit]

The [Consultative Group on International Agricultural Research](#) (CGIAR) published a map showing the countries and regions suffering most water stress.^[116] They are [North Africa](#), the [Middle East](#),^[117] [India](#), [Central Asia](#), [China](#), [Chile](#), [Colombia](#), [South Africa](#), [Canada](#) and [Australia](#). Water scarcity is also increasing in [South Asia](#).^[118] As of 2016, about four billion people, or two thirds of the world's population, were facing severe water scarcity.^[119]

The more developed countries of [North America](#), [Europe](#) and [Russia](#) will not see a serious threat to water supply by 2025 in general. This is not only because of their relative wealth. Their populations will also be more in line with available water resources.^[citation needed] North Africa, the Middle East, [South Africa](#) and northern China will face very severe water shortages. This is due to physical scarcity and too many people for the water that is available.^[citation needed] Most of [South America](#), [Sub-Saharan Africa](#), southern China and India will face water supply shortages by 2025. For these regions, water scarcity will be due to economic constraints on developing safe drinking water, and excessive [population growth](#).^[citation needed]



Africa [edit]

This section is an excerpt from [Water scarcity in Africa](#). [edit]

The main causes of [water scarcity in Africa](#) are physical and economic water scarcity, rapid population growth, and the [effects of climate change on the water cycle](#). Water scarcity is the lack of [fresh water](#) resources to meet the standard [water demand](#).^[121] The rainfall in [sub-Saharan Africa](#) is highly seasonal and unevenly distributed, leading to frequent [floods](#) and [droughts](#).^[122]

The [Food and Agriculture Organization of the United Nations](#) reported in 2012 that growing water scarcity is now one of the leading challenges for [sustainable development](#).^[123] This is because an increasing number of river basins have reached conditions of water scarcity. The reasons for this are the combined demands of agriculture and other sectors. Water scarcity in Africa has several impacts. They range from health, particularly affecting women and children, to education, agricultural productivity and sustainable development. It can also lead to more [water conflicts](#).

West Africa and North Africa [edit]

Water scarcity in Yemen (see: [Water supply and sanitation in Yemen](#)) is a growing problem. Population growth and climate change are among the causes. Others are poor water management, shifts in rainfall, water infrastructure deterioration, poor governance, and other anthropogenic effects. As of 2011,

water scarcity is having political, economic and social impacts in Yemen. As of 2015,^[124] Yemen is one of the countries suffering most from water scarcity. Most people in Yemen experience water scarcity for at least one month a year.

In Nigeria, some reports have suggested that increase in extreme heat, drought and the shrinking of Lake Chad is causing water shortage and environmental migration. This is forcing thousands to migrate to neighboring Chad and towns.^[125]

Asia [edit]

A major report in 2019 by more than 200 researchers, found that the Himalayan glaciers could lose 66 percent of their ice by 2100.^[126] These glaciers are the sources of Asia's biggest rivers – Ganges, Indus, Brahmaputra, Yangtze, Mekong, Salween and Yellow. Approximately 2.4 billion people live in the drainage basin of the Himalayan rivers.^[127] India, China, Pakistan, Bangladesh, Nepal and Myanmar could experience floods followed by droughts in coming decades. In India alone, the Ganges provides water for drinking and farming for more than 500 million people.^{[128][129][130]}



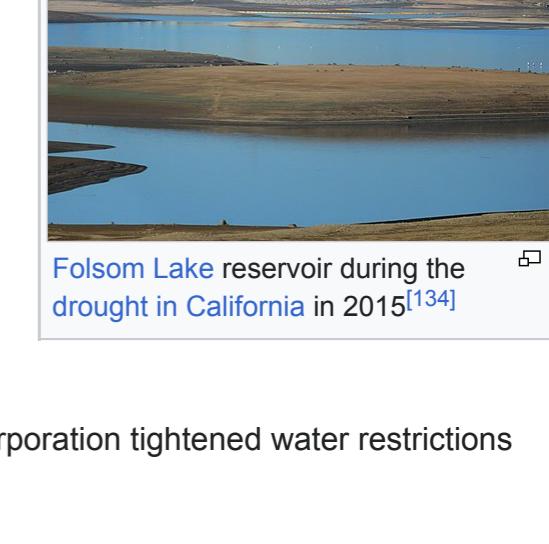
Even with the overpumping of its aquifers, China is developing a grain deficit. When this happens, it will almost certainly drive grain prices upward. Most of the 3 billion people projected to be added worldwide by mid-century will be born in countries already experiencing water shortages. Unless population growth can be slowed quickly, it is feared that there may not be a practical non-violent or humane solution to the emerging world water shortage.^{[131][132]}

It is highly likely that climate change in Turkey will cause its southern river basins to be water scarce before 2070, and increasing drought in Turkey.^[133]

America [edit]

See also: [Water scarcity in the United States](#)

In the Rio Grande Valley, intensive agribusiness has made water scarcity worse. It has sparked jurisdictional disputes regarding water rights on both sides of the U.S.-Mexico border. Scholars such as Mexico's Armand Peschard-Sverdrup have argued that this tension has created the need for new strategic transnational water management.^[135] Some have likened the disputes to a war over diminishing natural resources.^{[136][137]}



The west coast of North America, which gets much of its water from glaciers in mountain ranges such as the Rocky Mountains and Sierra Nevada, is also vulnerable.^{[138][139]}

Australia [edit]

By far the largest part of Australia is desert or semi-arid lands commonly known as the outback.^[140] Water restrictions are in place in many regions and cities of Australia in response to chronic shortages resulting from drought. Environmentalist Tim Flannery predicted that Perth in Western Australia could become the world's first ghost metropolis. This would mean it was an abandoned city with no more water to sustain its population, said Flannery, who was Australian of the year 2007.^[141] In 2010, Perth suffered its second-driest winter on record^[142] and the water corporation tightened water restrictions for spring.^[143]

Some countries have already proven that decoupling water use from economic growth is possible. For example, in Australia, water consumption declined by 40% between 2001 and 2009 while the economy grew by more than 30%.^[96]

By country [edit]

Water scarcity or water crisis in particular countries:

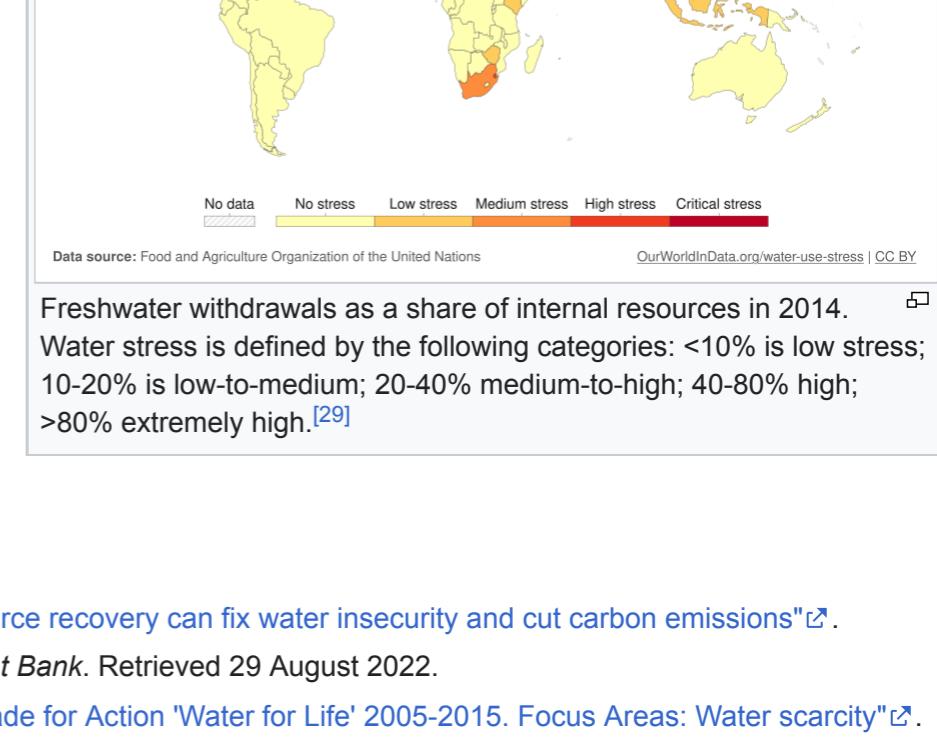
Water scarcity by country		[hide]
Australia · Egypt · India · Iran · Israel · Jordan · Kenya · Lebanon · Mexico · Pakistan · Saudi Arabia · Taiwan · Tajikistan · Turkey · United Arab Emirates · United States · Yemen		
Water crisis by country		[hide]
Democratic Republic of the Congo · Honduras · Iran · Lebanon · South Sudan		
Water supply and sanitation by country		[show]

Society and culture [edit]

Global goals [edit]

Main article: [Sustainable Development Goal 6](#)

Sustainable Development Goal 6 aims for clean water and sanitation for all.^[144] It is one of 17 Sustainable Development Goals established by the United Nations General Assembly in 2015. The fourth target of SDG 6 refers to water scarcity. It states: "By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity".^[10]



See also [edit]

- Peak water – Concept on the quality and availability of freshwater resources
- Water conservation – Policies for sustainable development of water use
- Water footprint – Extent of water use in relation to consumption by people
- Water issues in developing countries – Water issues and problems in developing countries are diverse and serious
- Water security – Goal of water management to harness water-related opportunities and manage risks
- All pages with titles containing water crisis

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THE SUSTAINABLE DEVELOPMENT GOALS





GLOBAL COMMISSION on the
ECONOMICS OF WATER



The What, Why and How of the World Water Crisis:

Global Commission on the Economics of Water Phase 1 Review and Findings

The What, Why and How of the World Water Crisis:

Global Commission on the Economics of Water Phase 1 Review and Findings

March 2023



www.watercommission.org

The Global Commission on the Economics of Water has published the following two documents in March 2023. The Commission will be issuing its final report in 2024.

Turning the Tide: A Call to Collective Action was formulated by the Co-chairs of the Global Commission on the Economics of Water, drawing on the combined experience, insights and views of the Commission.
turningthetide.watercommission.org.

The What, Why and How of the World Water Crisis: Global Commission on the Economics of Water Phase 1 Review and Findings, a research document that reviews and updates data and knowledge relating to the global water crisis, was formulated by the Lead Experts of the Global Commission on the Economics of Water, and draws likewise on the contributions of the Commissioners and Advisors.

watercommission.org/publication/phase-1-review-and-findings

Dedicated to Inge Kaul (1944–2023), our erstwhile colleague on the Commission, whose academic legacy in the area of global public goods has inspired scholars and policy makers



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01

A Provocation

WHAT? The world is at a crossroads. Business-as-usual is damaging what the water cycle can deliver to ensure sustainable development for all. This requires a new framework that goes beyond conventional economic thinking to adopt a systems approach to water, the economy and societies, including full consideration of the diverse colours of water — blue water (rivers, aquifers, lakes and water storages) and green water (the water in soils – soil moisture – supporting all vegetation and evaporation from land) and across geographical scales. It is based on the knowledge that water shapes transformational economic, sociocultural, ecological and environmental change.

WHY? The water cycle is one of the essentials for all life on Earth and for a just, sustainable and resilient economy. It is a global common good linking all 17 Sustainable Development Goals (SDGs). It is deeply interconnected with biodiversity and the climate while providing a stable foundation for human well-being and ecosystem health, and hence is a necessity for socio-economic and ecological prosperity.

Many intractable sustainable development challenges stem from the systemic water crisis of having too little, too much and too dirty water. Humans have been altering the global water cycle for centuries, but the new challenge facing the world is that we are now changing the source of all freshwater — precipitation. This alteration is caused by climate and environmental change at the regional and global level, combined with the local changes of the water cycle, caused by misuse and overdraft. The key drivers of this crisis include increasing population, economic development, resource-intensive or inefficient technology, urbanisation, deep under-investment, corruption, climate change and inequitable and irrational consumption. Existing economic, legal, institutional and political barriers hamper policy making for sustainable water governance from the local to the global level. Without a change in how we manage water and the economy, the water crisis will deepen, exacerbating existing inequalities and injustice. Millions already die each year from consuming contaminated water and food. An additional 1.3 billion people could become severely food

insecure by 2050 from heat stress and water insecurity with irreparable loss of ecosystems and biodiversity under business-as-usual. A failure to control water withdrawals and consumption will magnify climate risks and accelerate the biodiversity crisis, affecting the well-being of the poor and the rich alike.

The global economy and most contemporary societies inadequately consider our deep cultural, faith and historical relationships with water, the many non-market values (e.g. cultural, relational, ecological) of water, economic and livelihood interdependencies with the water cycle, and the multiple economic sectors and end-uses of water. Universal and equitable access to water is as critical as access to food, energy and health systems. Past and current responses to the water crisis are embedded in locked-in legacy institutional arrangements that are not fit-for-purpose at the local to the global across time and space. The Stern (2007) and Dasgupta (2021) reports have outlined the economic and all-of society thinking, and actions needed to respond to climate change and biodiversity loss. Building on those reports and going beyond, we highlight how collective action failures linked to water might be overcome and provide a critical missing link between the implementation of the sustainable development, climate action and biodiversity agendas.

HOW? The response is to value and govern the water cycle as a global common good because every country needs a stable water cycle, climate system and healthy ecosystems. This interconnectedness makes water a critically important global asset that can only be secured through collective action across the entire world. Here, we diagnose the water crisis, emphasise the costs of inaction and present the elements of a new framework for the economics of water and beyond for a safe and just water future. Our report is a first step, to open multidimensional and multi-level dialogues to accelerate local, national and regional actions, initiate global negotiations and co-create a compact for water as a global common good. This compact will be based on a series of societal dialogues across multiple communities and stakeholders in 2023–24 to deliver a framework for actions that: rethink policies, revise regulations and reallocate water to deliver affordable access for all. This approach demands “systems thinking” that fully accounts for Earth Systems; new governance with a focus including justice and equity; an improved financial and knowledge architecture; methods to respond to governance and institutional lock-ins; sharing and diffusion of contextual innovation and technology; incentives to account for non-market values; and widespread adoption of water accounting and valuation. In sum, it demands a global transformational change using water as an elemental and organising principle.

1.1

The proposition

Many approaches, reports and commissions have attempted to address the challenges of water at multiple levels. What is the unique proposition that the Global Commission on the Economics of Water (GCEW) provides?

First, it identifies the systemic crisis of the global water cycle, based on new evidence and science.

Second, it uses a “systems lens” to view water not as a sector, an input, or an adverse outcome, but as an organising principle to connect across the SDGs, climate action and biodiversity conservation.

Third, it establishes a transformational goal for the global economy and all human societies: to treat water as a global common good — to respond to a crisis of the global water cycle and to resolve the multiple local and regional crises of too little, too much, or too dirty water.

Fourth, it presents a set of transition goals across economic, social and natural systems for a collective response to the multidimensional, multi-level global water crisis.

Fifth, it shows how these system transitions need collective action built around a new social contract between citizens, governments, businesses, communities and civil society, which functions effectively from the local to the global.

Sixth, it highlights the opportunities for adopting a transformational goal of treating water as a global common good, noting that the full realisation of these benefits requires effective multilateral actions and diversified partnerships. We contend that treating water as an organising principle and water as a global common good will revitalise multilateral actions and, in a fragmented and contested world, promote prosperity, human well-being and ecosystem health for all by 2050.



02

What is the Water Crisis?

Science shows that humans are altering the water cycle at all scales, from the local to the global, changing the source of all fresh water, precipitation and triggering extreme water events. Combined with unsustainable use, this exacerbates the water crisis at multiple scales from the local to the global. We outline the social, economic and political drivers of this crisis. Through a “systems thinking” approach, we “connect the dots” between water, climate change, biodiversity loss and land use change. We emphasise the crucial juncture faced by the global community that requires immediate and decisive action.

We require a transformational change and a new framework for the economics of water: thinking that embraces water as an organising principle for sustainable development across all SDGs; risk mitigation that supports resilience; acknowledging the multiple monetary and non-monetary values of water; and actively responding to injustice.

2.1 The water cycle

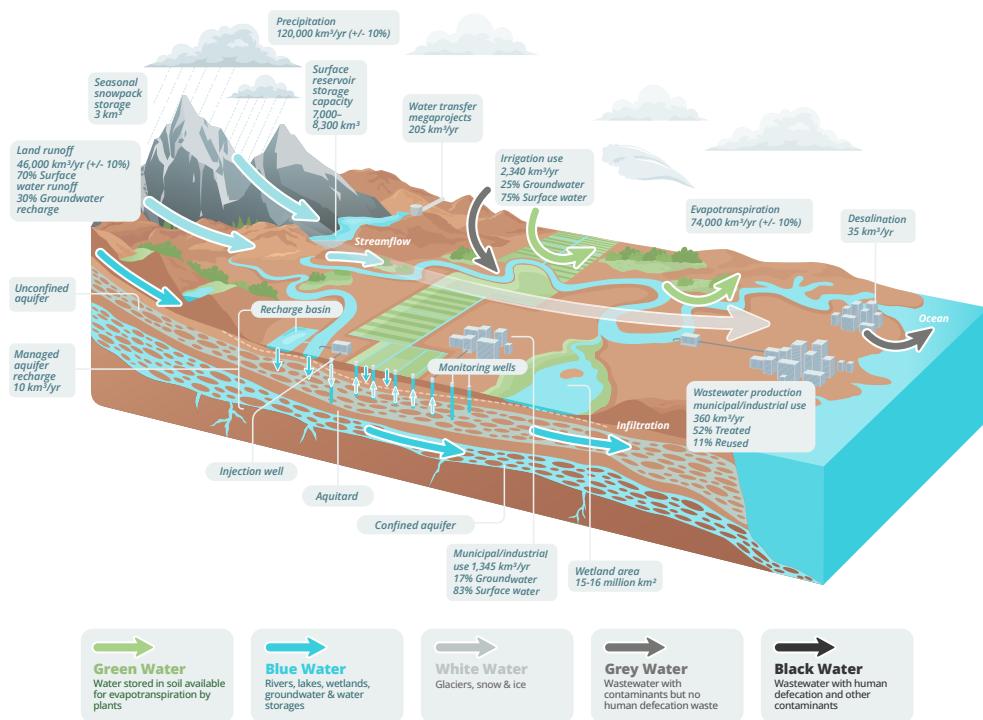


FIGURE 2.1 The water cycle

SOURCES: Adapted from Scanlon et al. (2023) with supplemental data from Caretta et al. (2022); Davidson and Finlayson (2019); and Douville et al. (2021)

The water cycle is the basis of all life and is inseparably interconnected with society, the environment and the economy. This water cycle forms a local to global common good (see Box 2.1) because it affects every key aspect of ecological and human life, including all 17 Sustainable Development Goals (SDGs). This interconnection of water, ecosystems and societies is visible as the freshwater stocks (e.g. soil moisture, water in rivers and lakes, water storages and groundwater) in the water cycle change. Those alterations of flows are affected by human activity (e.g. ecosystem degradation, land-use change, irrigation and industry) from different regions that change the state of water (e.g. from frozen to liquid to vapour), where and when water is available and for what uses (Figure 2.1).

Within the water cycle, different colours of water can be identified, blue and green (Falkenmark and Rockström, 2006). Blue water is the fresh water in streams, rivers, aquifers and surface water storage that provides drinking water and grows 30% of the world's food, besides sustaining all freshwater aquatic biodiversity. Green water is the soil moisture, flowing as evaporation and transpiration through plants, powering rainfed food production and all living species in nature.

BOX 2.1 The Common Good

The economic definition of water is different and based on its various attributes: it can be a natural resource, a human right and a commodity, among other things. Each attribute places a different economic value (based on the level of its excludability and rivalry) to water and different assumptions about how to govern it.

Water is often defined as a public good, with flood control offering a good example. However, several waves of privatisations in the 1980s advocated for addressing water as a private good (excludable and rival) to be offered in competitive markets under the reasoning that the private sector would attract the necessary funding for the sector. This, however, has not materialised, instead creating more inequalities and inefficiencies (Castro, 2007; Schwartz and Schouten, 2007). Other concepts have been used to describe shared water at the grassroots level, such as “common-pool resources” that have an attribute of a public good (non-excludable) and an attribute of a private good (rival) due to its scarcity — a groundwater aquifer is one example. The concept of a common-pool resource implies a need for the collective governance of water often by communities to ensure it is managed in a sustainable and equitable way (Ostrom and Ostrom, 2004). Water is also seen as a global public good, especially when describing transboundary waters with a view to achieving a just distribution of water resources that meet the increasing needs of the world’s growing population (Kaul et al, 1999).

Given the planetary-scale importance of green and blue water, both of which are at or close to their planetary limits, the Global Commission on the Economics of Water proposes that all freshwater (blue and green) be regarded as a global common good (Porkka et al., 2022). As a concept, the global common good offers a holistic view of the economic value of water by capturing its varying definitions not only as an outcome but as a process of addressing the associated scarcity and equality challenges. Indeed, the common good approach creates the space for more collective action around water-related challenges that can accommodate diverse interpretations of economic value based on local context and national jurisdiction (e.g. common-pool, private or public good). The common good approach has several key attributes, which include: (a) a challenge that requires intense collaboration and collective intelligence, (b) the co-creation of commonly shared goals, (c) attention to designing how to achieve key objectives, and (d) ways to share the risks and rewards of economic activity (Mazzucato, 2023). Section 4 lays out how this new framework for the economics of water could be structured.

The green-water flux is the evapotranspiration of precipitation and soil moisture by plants when water is transformed from a liquid to vapour to return as precipitation again. How green and blue water are used is connected to economic activities (Hoekstra and Chapagain, 2008) and most often is taken for granted (Figure 2.1). We note that the many non-market values of water, primarily associated with ecosystem services (provisioning, supporting and cultural), are frequently not included in economic decision-making (Manero et al., 2022).

2.2

A safe operating space

Critical to achieving the SDGs is directing economic growth towards a safe and just water future (see Chapter 4). But what does a safe and just water future look like? A starting point is to define the safe space in which societies can satisfy their water needs (lower boundary) while ensuring the water cycle remains within a manageable range (upper boundary).

To estimate the lower boundaries, we must reconsider basic water needs and go beyond the minimum water needed for drinking, cooking and sanitation, which is, typically, 50 litres of blue water per person per day. It should also include the green and blue water that serves all human needs. This lower boundary, as an average of green and blue water requirements per person, could be 1,200 m³ per year.

The world is at or very near to its upper boundaries of water use. This demands a rethinking of use patterns to maintain the Earth's ability to support humans and the species with whom humans share this planet, to meet the SDGs, and to limit as much as possible further global warming. For human survival, the global water cycle must remain within a manageable range for both green and blue water available limits by establishing water use patterns within these ranges and ensuring that global precipitation remains within the available Holocene range of some 120,000 ± 10% km³ per year (Figure 2.2).

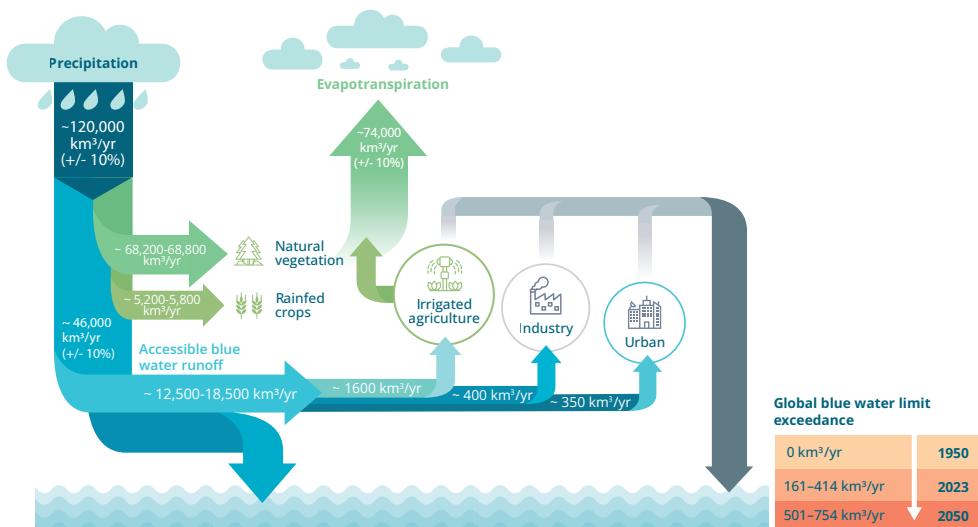


FIGURE 2.2 The water cycle, global water consumption by sector and blue water consumption exceedance
SOURCE: Authors. Details of data sources and calculations provided in Grafton, Krishnaswamy and Revi, 2023

To secure communities against water shocks and to maintain the necessary flows of green and blue water across different scales (i.e. local to global), new thinking on comprehensive water requirements for dignified and equitable human lives is necessary. This must include estimating and adapting to the costs of the accelerating risks and shrinking sources of freshwater supply due to human actions, changing precipitation, extreme weather events or melting of previously stable glaciers (Srivastava et al., 2022).

Economic thinking must fully value both green and blue water resources and flows, measure, and act to ensure water budgets remain within sustainable boundaries. As part of a new framework for the economics of water the world must embed the common good at the heart of how we value, govern and finance water — and how we collaborate to tackle the biggest water-related challenges.

BOX 2.2 Water consumption and water use

Water consumption is the evaporation and transpiration of water, transforming liquid into water vapour that becomes part of the atmospheric water cycle. Water Use is the application of liquid water from any source (river, aquifer, rainfall) to any specific purpose (washing, cooking, generating power, growing crops, etc.). Total Water Use comprises:

1. **Consumed Fraction** – the proportion of water that is converted into vapour (and, thus, is no longer available for local use) by evaporation and transpiration. The Consumed Fraction comprises:
 - a. **Beneficial consumption:** evaporation or transpiration for the purpose for which the water was withdrawn (e.g. growing a crop, cooling a power station);
 - b. **Non-beneficial consumption:** evaporation or transpiration that does not contribute to the intended purpose for which the water was withdrawn (e.g. growing weeds).
2. **Non-consumed Fraction** - the proportion of water use that is **not** converted to vapour and that returns to the environment in liquid form as:
 - a. **Recoverable return flows:** water that reaches an aquifer or stream and is potentially available for reuse at another time or place;
 - b. **Non-recoverable return flows:** water that reaches a saline sink, including the ocean, or is otherwise not economically recoverable.
3. **Changes in Water Storages** (expressed as a fraction of the water withdrawal)

The sum of the Consumed Fraction, Non-consumed Fraction and Changes in Water Storages must equal 1.0.

Source: Willardson et al., 1994

2.3

Crossing global water limits

The global water system crisis is one of too little, too much, or too dirty water at multiple scales. These impacts encompass ecohydrological, social, economic and governance crises, each with profound implications for growth, sustainable development, justice and inclusiveness (see Section 4.1) (Gupta and Lebel, 2020; Zwarteeven and Boelens, 2014; Goldin, 2010; Ahlers and Zwarteeven, 2009). This crisis spans from the local, provincial and fluvial to national, transboundary and global scales (Harris et al., 2017). Global population and income growth and changes in per capita consumption of food, feed, fibre, timber and energy have caused unprecedented rates of land and freshwater use within agriculture. The blue water withdrawals have increased from 500 km³ in 1900 to about 2,000 km³ in 1970 and more than 4000 km³ in 2022 (Ritchie and Roser, 2022b; Müller Schmied et al., 2021; Boretti and Rosa, 2019; UNESCO and UN, 2019). This has contributed to global groundwater depletion (Figure 2.3) and degradation of riparian environments (Vörösmarty et al. 2010).

Human water use directly affects more than 70% of the global, ice-free land surface (IPCC, 2019b). Land use patterns play a crucial role in the climate systems and the water cycle from the local to global scales. For example, some places receive nearly half their rainfall from biodiversity-rich regions or hotspots (Keys et al., 2016). From 1961–2013, the annual area of drylands in drought with severe water stress has increased, on average, by more than 1% per year, with sizeable inter-annual variability (Mirzabaev et al., 2019). In 2015, about 500 (380–620) million people lived in areas which experienced desertification and associated water stress (Licinio and Wong, 2021). Human impacts on the water cycle have contributed to multiple crises including ecohydrological, social/health, economic and governance crises.

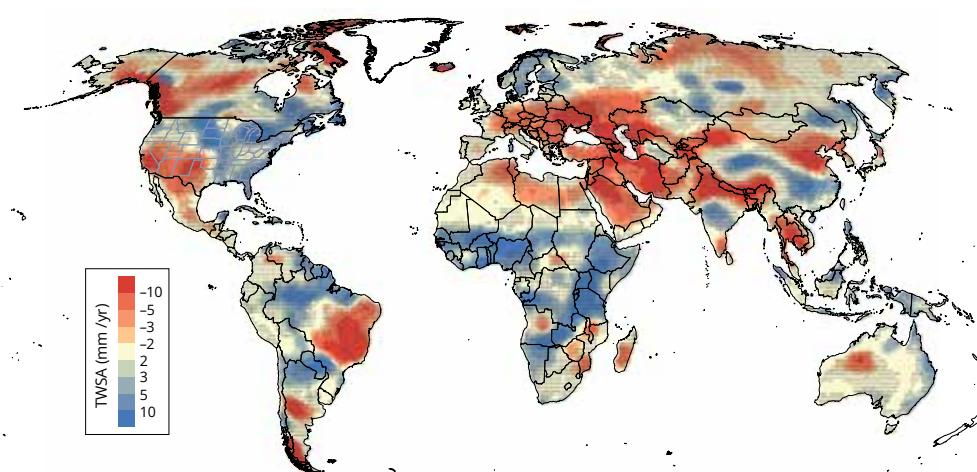


FIGURE 2.3 Trends in total water storage anomalies (2002–2022)

SOURCE: Scanlon et al., 2023

It is an ecohydrological crisis because direct human-driven actions, separate to climate change, are responsible for the projected increased water scarcity by 2050 and 2100 (Graham et al., 2020) and because we are crossing all water boundaries (i.e. blue and green water) (Bunsen et al., 2021). Groundwater depletion has reached high levels in several places (Bierkens and Wada, 2019). Surface water variations exceed proposed boundaries worldwide (Porkka et al., 2022), and the green water planetary boundary may already have been transgressed (Wang-Erlundsson et al., 2022: 380). Crossing freshwater and other planetary boundaries (climate change, biosphere, nitrogen, phosphorus and land-system change) will threaten human existence (Steffen et al., 2015). In addition to crossing water boundaries, water quality has been badly affected worldwide by a mix of chemicals, heavy metals, biological, thermal and other pollutants, with enormous consequences for human life, health, livelihoods, and ecosystems (UNEP, 2019a). Today, 80% of municipal and industrial wastewater is discharged untreated. Agriculture-related pollution levels for phosphorus and nitrogen may already be higher than what is sustainable on a global scale (Rockström et al., 2009).

It is a social and health crisis because some 2 billion people lack access to safely managed drinking water services (UN Water, 2022), some 3.6 billion lack access to improved sanitation services (WHO and UNICEF, 2022) and 670 million or so practise open defecation (WHO, 2019a), creating health risks (Saleem et al., 2019). Additionally, millions of small landless farmers in the Global South have limited or no access to water for agriculture; but smallholder farmers grow as much as a third of the world's food (Lowder et al., 2021), making water access and affordability a challenge due to lacking access and property rights. Water-related disasters such as droughts, storms, floods and extreme temperatures have already directly killed around two million people in the last 50 years, mainly in the Global South (WMO, 2021: 17; Mohanty et al., 2020), and 700 million people are at risk of displacement by 2030 (HLPW, 2018).

BOX 2.2 Two large water-related disasters in 2022: Florida/USA and Pakistan

In September 2022, Hurricane Ian caused social, infrastructural and environmental damage in the southern states of the US (Li et al., 2022). The hurricane was one of the five strongest recorded in the US (a Category 4). More than 140 people died, and 11,000 homes were destroyed. Damage estimates show that the costs of extreme weather events are increasing over time, and the total cost of Hurricane Ian alone is estimated at between USD 41–70 billion (Forbes, 2022).

In 2022, following rainfall that was 190% greater from June to August relative to its 30-year average (Royal Geographical Society, 2022), all provinces of Pakistan were flooded and around 33 million people directly affected (World Bank, 2022). Ten million children needed support, and thousands of homes were damaged or destroyed. The total economic losses were estimated at around USD 15.2 billion. In the aftermath of the flood, the greatest challenge was the health crisis that emerged, with malnutrition, diarrhoea, malaria, dengue fever, typhoid, acute respiratory infections and painful skin conditions. The damage ranged from USD 10 billion (+ 4% of its GDP) (Nugent, 2022) to USD 14.9–16 billion (World Bank, 2022).

Exposure to water-related diseases is growing worldwide, with some 1.4 million people dying annually (UNEP, 2019b) and 2 billion people using contaminated water, increasing their risk of water-related sickness (WHO and UNICEF, 2022), with disproportionate impacts on women and girls. These water-related diseases and contaminants (fluoride, arsenic, lead and more) can cause cancer, reduce mental cognition and limit nutrient absorption and growth, resulting in stunted growth and deformation among children and abortion or severe health impacts on young mothers (Ghosh and Mukhopadhyay, 2019). The health impact of polluted water due to arsenic, fluoride, iron and nitrates is furthered by increased groundwater reliance. Water scarcity is driving reliance on groundwater that carry heavy inorganic pollutants load. At the same time, improper sanitation and industrial waste management are increasing the organic contaminant load.

It is an economic crisis because economic development depends on water, from withdrawal to consumption and disposal. Inadequate water supply affects economic growth. Extreme weather events reduce economic growth and increase inequalities. Economic development slows through: (i) misallocated or inefficiently used water; (ii) water-related hazards (floods and droughts) destroying property and lives; (iii) inadequate access and unaffordable safe water and sanitation impacting health, nutrition and education; and (iv) water shortage increasing the likelihood of internal conflicts and disputes that reduce incentives for investment (World Bank, 2015).

It is a governance crisis at multiple levels of decision-making manifested at multiple scales (Gupta et al., 2013). At a global and national level, no water governance organisation focuses on the water cycle; water governance is dispersed between some 30 UN agencies, non-UN agencies and Conventions. At the transboundary level, hundreds of agreements between riparian states have developed over the centuries. Some have led to cooperative advancement while others to contestation.

Challenges to be overcome at a national scale include historic colonial legacies, capacity shortages, financial constraints, rent-seeking behaviour, and possibly regulatory capture and corruption (Lele et al., 2018; Molle, 2009a; Grafton and Williams 2020). Water decision-making is, typically, at a local level and if undertaken at the national level, it is typically dispersed between multiple ministries. Frequently, water laws and allocations are based on preferences of influential interests in return for political support and funding (McCulligh, 2018) that can result in over-extraction and impose costs on others (Tetreault and McCulligh, 2018) worldwide, especially marginalised communities.

Water has been a transboundary governance challenge for centuries, where states have argued about sharing water and water-related responsibilities. At the river basin level, frequently, there are conflicts between upstream and downstream users and between rural farmers and urban centres. Efforts to resolve them through river basin organisations are ongoing. At a local level, the conflict is often between the municipality and different local groups and between the local groups themselves (e.g. large farmers versus smallholders).

BOX 2.3. Water-related tensions

Water conflicts and cooperation can be traced back to about 5000 BCE. There are about 700 transboundary agreements today concerning the world's 250 shared rivers and the 592 transboundary aquifers (Gupta and Dellapenna, 2021; IGRAC, 2015; Dellapenna and Gupta, 2009). Despite these agreements, in the transboundary arena between countries, there is growing evidence of water-related tensions between riparian countries, whether on the Isfara River (Uzbekistan, Tajikistan and Kyrgyzstan), the Nile (Egypt and Ethiopia: Grand Ethiopian Renaissance Dam), Indus River, Mekong, Colorado or elsewhere (OSU, 2023).

The 1971 Ramsar Convention on Wetlands, which aims to protect wetlands of international importance, is a global agreement with almost universal membership that provides a framework for wetland conservation. The 1992 UNECE Water Convention and the 1997 UN Watercourses Convention aimed at governing water systems have yet to be ratified by more than 25% of countries, reflecting the reluctance of countries worldwide to accept general principles of water governance and water sharing (Gupta, 2016). The centrepiece of the UN Watercourses Convention (1997) is the requirement that countries equitably share water in the shared watercourses. This questions the original principle of absolute territorial sovereignty and is complemented by the principle of no significant harm (Gupta, 2016). There remain substantial challenges to implementing equitable sharing and the no harm principle at the transboundary level (McIntyre, 2020; Schmeier and Gupta, 2020; Tanzi, 2020), and to include green water (Keys et al. 2017). In the Anthropocene, water use and consumption limits imply further sharing between uses of water at multiple scales, for example, through prioritising the human right to water and sanitation — such as smallholders or large farmers, the rights of Indigenous Peoples, the role of water procurement and the rights of local or foreign users.



2.4

Water, Energy, Food (WEF) and environment nexus

Everyone is affected by the water crisis, but the greatest harm is faced by at-risk communities in the Global South, where the costs of hazards (potential loss), vulnerabilities (susceptibility to loss) and exposure (contact with the hazard) are most acute (Mohanty and Wadhawan, 2021). The nexus between water-food-energy leads to complex consequences that are felt by all (Figure 2.4).



FIGURE 2.4 Multiple risks and hazards, vulnerabilities and exposure

SOURCE: Adapted from Simpson et al., 2021: 492

The interconnectedness between food and water is most evident in the food trade (Pastor et al., 2019). Water and food security are closely linked to trade. The share of food, measured in calories, crossing an international border rose from 12% to over 19% over the past 40 years (Laborde and Deason, 2015). This global food trade feeds hundreds of millions of people, noting that 20% of cereals in low-income economies is imported (FAO, IFAD, UNICEF, WFP and WHO, 2019), and has, to date, promoted a more equitable distribution of food globally than otherwise (Wood et al., 2018). Nevertheless, there are trade-offs in that the export of blue water intensive crops from arid and semi-arid locations exacerbates water insecurity in such regions (Hoekstra and Chapagain, 2008).

Water (quality and quantity) is closely connected to food security and nutrition. At a household level, water quantity determines production needed for food preparation, and the quality of water for drinking and sanitation affects the absorption of nutrients. There are many connections between water and the economy, such as energy production, supporting economic development and food affordability (Figure 2.5), noting the global water cycle is changing, which is already directly affecting availability and stability.

The food price shocks of 2007–08 and 2021–22 illustrate the nexus between Water-Energy-Food (WEF) and interconnectedness of human and environmental systems (Figure 2.6). While water is not the primary source of the shock in these two cases, extreme weather events (too much and too little water) adversely affected agricultural production levels. The 2007–08 crisis was, in part, caused by growing more water-intensive biofuels at the expense of overall food production (Headey and Fan, 2010). The 2007–08 food price crisis put millions of additional people in hunger and revealed the fragility of the global food system. The 2021–22 food shock, in addition to extreme drought and flood events, was the product of conflict, energy crisis, rising costs of production and reduced accessibility/affordability of fertilisers, all of which together have dramatically increased food prices.

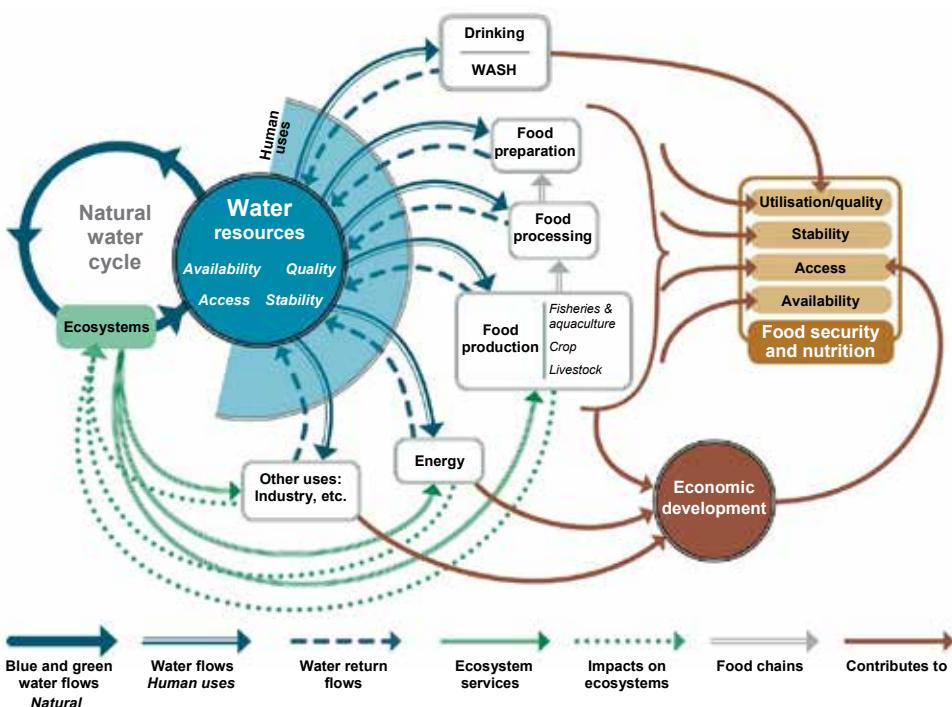


FIGURE 2.5 Water and food security connections

SOURCE: Adapted from HLPE, 2015

A WEF lens is needed to respond to system shocks by “connecting the dots” rather than seeing only the immediate causes (Kholod et al., 2021) and to include water within climate mitigation and adaptation policies (Miralles-Wilhem, 2022). WEF connects policies to shocks whereby a drought in one country is transmitted to others via changes in food exports or imports and it recognises that national policies (e.g. food export restrictions) can magnify the costs to others. Operationalising WEF is about ensuring food, water and energy security are resilient to shocks (e.g. extreme weather events, conflicts) by planning with all stakeholders from civil society to the private and public sectors (Pahl-Wostl, 2009) for worst-case outcomes while accepting the legitimacy of diverse knowledge systems (epistemic and recognition justice) (Henry and Dietz, 2011; Armitage, 2008).

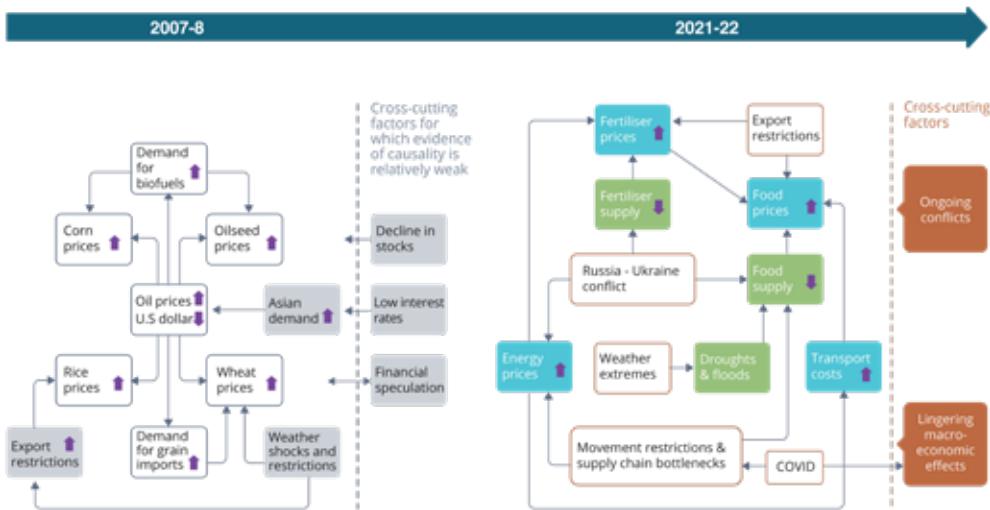


FIGURE 2.6 WEF Nexus: Principal causes of the 2007–08 and 2021–22 food price shocks

SOURCES: Headey and Fan, 2010; Katic and Grafton, 2023

2.5

A safe and just limit

Policy and economic choices scarcely consider future generations. Investments are often made to create an adequate financial return, but many water-related investments that generate a high positive social rate of return may not necessarily generate a direct financial return (OECD, 2022). Most of the underlying drivers of water and environmental problems are ignored, and poor water governance continues. Consequently, business-as-usual can both create and aggravate existing injustices (Hartwig et al., 2022).

A safe and just limit calls for redistributing water between different uses and users at all levels of governance, and water sharing to protect water flows in basins and to prevent further depletion of aquifers (Marston and Cai, 2016). It requires: (a) Efforts to improve groundwater management and thus reduce saltwater intrusion; (b) Improvements in water quality by reducing point and non-point pollution and implementing monitoring measures to prevent pollution and (c) Strategies to respond to extreme water events that hugely impact society in terms of direct damage and reductions in water quantity and quality, noting that for extreme events, insurance is often unaffordable to many parts of the world (Global Commission on Adaptation, 2019). Even where insurance for water-related damages is affordable, insurance companies face major challenges in insuring extreme weather events (Ghosh, 2020; Ghosh and Raha, 2022; Keucheyan, 2018). The issue in all these requirements is, who will bear the costs of economic, infrastructure and other damages? This question calls for a justice framework to be central in regulating the water sector to live within water boundaries, otherwise the world will never achieve its 17 SDGs.

2.6

The world at a crossroads

The world is at a crossroads regarding what the water cycle can deliver to ensure sustainable development for all. Anthropogenic impacts on water are causing unprecedented water extremes and will get worse with business-as-usual (Graham et al., 2020). We must live within water (blue and green) limits, but we have already crossed the blue water consumption boundary (Porkka et al., 2022; Rosa et al., 2019) and the green planetary water boundary (Wang-Erlandsson et al., 2022). Figure 2.2 shows the water cycle in its colours (blue and green) and the hues of blue water (grey and black). This figure highlights that we have passed the safe and just global blue consumption limit through unsustainable groundwater depletion and inadequate stream flows by 161–414 km³/ year in 2023 and potentially by 501–754 km³/ year by 2050. We are rapidly approaching, with business-as-usual in our economic systems and societies, the limits to growth (Herrington, 2021).

Without a change to business-as-usual, this blue-water limit exceedance could be 30% greater by 2050, magnifying climate risks and biodiversity loss and affecting water and food security. With business-as-usual the Earth will lose its resilience (Grafton et al., 2019) to ensure environmental and water conditions stay within the safe and just zone that enables life and protection of water-related ecosystem services (Gupta et al., 2023).

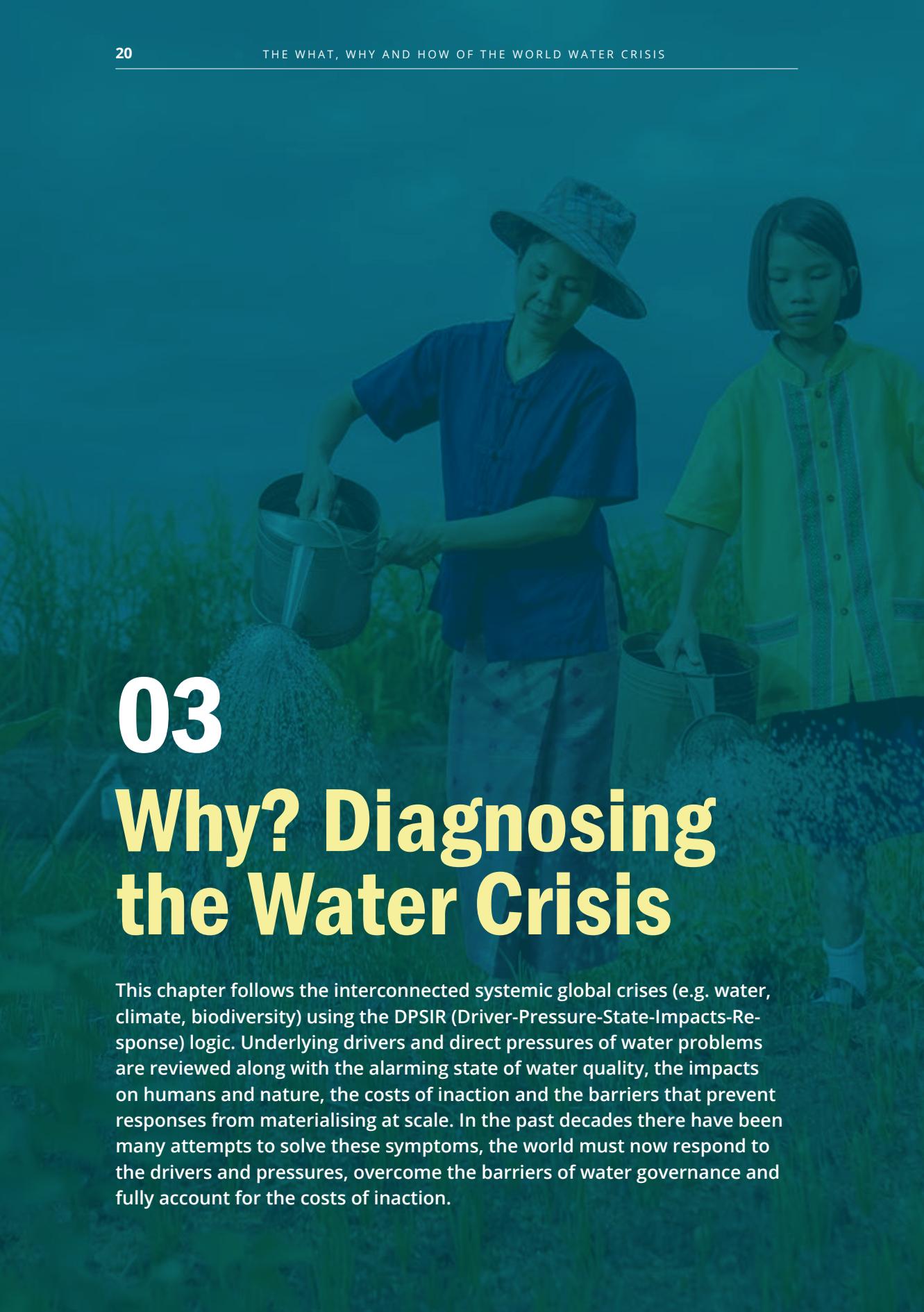
Returning to a safe blue water consumption limit cannot be about reducing blue water consumption alone and requires considerations on green water consumption for crops to feed the world's growing population. This requires reallocating and reevaluating water resources (Rammelt et al., 2022), protection of water-related ecosystem functions and a global water justice approach (Gupta et al., 2022).

Fresh thinking and collective actions are needed that consider the costs and benefits of reallocation of water between uses (e.g. different crops), users (e.g. between households, nature and industry) and scales (e.g. from local to transboundary level) at a local, national and global scale. This demands fresh thinking that recognises the existing lock-ins and injustices, responds to them, and delivers a safe and just future. Without transformational change and accounting for justice, it will not be possible to promote sustainable water use globally (Gupta and Lebel, 2020) and to ensure sustainable food systems (Béné et al., 2019), nor will food-water-energy systems be resilient to shocks (Matthews et al., 2022).

Policy makers face a stark choice. Collectively, they can continue with business-as-usual, generating significant socio-ecological risks and inequalities and, consequently, local, regional and global social and political instability and conflict. Or they can value and govern the water cycle as a Global Common Good that embeds justice across multiple jurisdictions and between generations. This change requires a new framework for the economics of water, a thinking based on a systems approach that embraces water as an organising principle for sustainable development; risk mitigation that builds resilience (Ligtvoet et al., 2018: 86–87); acknowledges the multiple monetary and non-monetary values of water; and actively responds to injustice. Our collective future depends on enacting this transformational change.

03

Why? Diagnosing the Water Crisis

A photograph showing a man wearing a wide-brimmed hat and a blue t-shirt, and a young girl in a green dress, both carrying metal buckets on their heads in a rural, possibly arid, environment. They appear to be collecting or transporting water.

This chapter follows the interconnected systemic global crises (e.g. water, climate, biodiversity) using the DPSIR (Driver-Pressure-State-Impacts-Response) logic. Underlying drivers and direct pressures of water problems are reviewed along with the alarming state of water quality, the impacts on humans and nature, the costs of inaction and the barriers that prevent responses from materialising at scale. In the past decades there have been many attempts to solve these symptoms, the world must now respond to the drivers and pressures, overcome the barriers of water governance and fully account for the costs of inaction.

3.1

Underlying drivers and direct pressures of the water crisis

We diagnose the global water crisis using the **Drivers** (underlying causes), **Pressures** (direct causes), **States**, **Impacts** and **Responses** (DPSIR) framework (Figure 3.1).

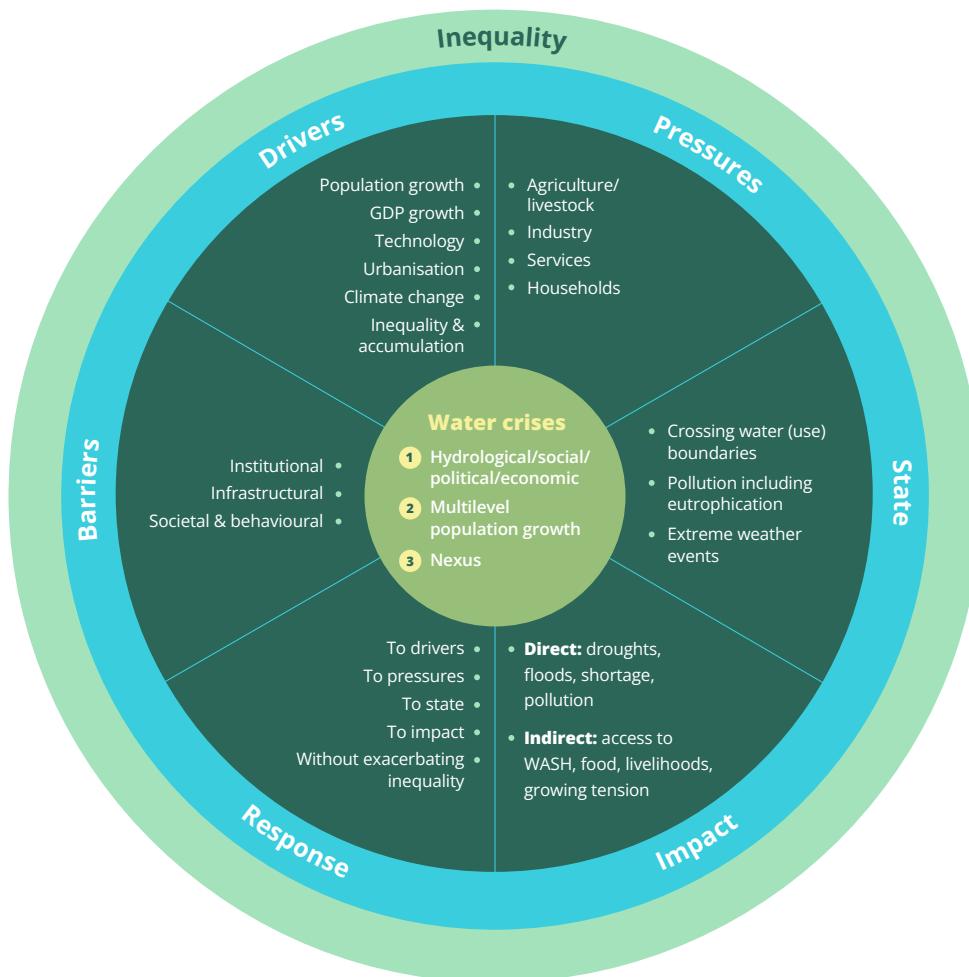


FIGURE 3.1 DPSIR applied to water (COP-27 Water)

Multiple drivers shape the pressures, which affect past, current and future generations. These include broader trends such as (i) population growth, (ii) economic development, (iii) urbanisation and (iv) climate change, and actionable elements such as (v) underinvestment, (vi) technology and innovation, noting that (vii) inefficiency and (viii) inequality are cross-cutting drivers of water and climate change problems as outlined below.

(i) The global population is expected to reach 9.7 billion in 2050, with the greatest growth in sub-Saharan Africa and South Asia (UNDESA, 2022; Gillespie et al., 2007). This population growth will substantially increase demands for water, food and energy (Chen et al., 2016).

The growing world population, especially the increasing number of high-consuming people, has led to an intensification of agriculture and animal husbandry, and increasing water use and consumption (UNEP, 2019b). Global water withdrawals are expected to grow by another 20–30% by 2050, compared to 2010 (Mekonnen and Gerbens-Leenes, 2020). Agriculture and animal husbandry directly impact blue and green water use, consumption and pollution. Almost 20% of global water consumption by irrigation is sourced from aquifer depletion (Wada et al., 2012). More than half of this aquifer depletion occurs in India, China, the US and Pakistan. In addition, many rivers are deteriorating from over extraction and reduced runoff (Döll et al., 2009).

Countries with both food deficits and growing populations will need to reduce food waste and have more rapid domestic food supply growth than the world's largest food-producing countries to avoid an increase in the global food deficit (Grafton et al., 2017). Current food demand is met, but hundreds of millions remain food insecure and there is unnecessary food waste. Global agricultural export (USD 1,492 billion in 2020) is critically important to meet current and future food demands as the share of food traded (measured in calories) represents about 20% of total consumption (FAO et al., 2022: 47). While food trade mitigates food insecurity (Zimmermann et al., 2018), the additional food will require water and energy (Ritchie and Roser, 2022a). This creates cross-border dependencies (D'Odorico et al., 2019) that need to be effectively managed at a global scale (Katic and Grafton, 2023).

(ii) Water in economies is used for extraction, production, distribution, consumption and disposal, and so is linked to GDP growth. Water is required for energy production (e.g. hydropower and cooling) and for the mineral and resources sectors (Boretti and Rosa, 2019: 3; D'Odorico et al., 2019; Jin et al., 2019). Some industries extract water from aquifers beyond recharge levels (UNEP, 2019b; Famiglietti, 2014) and water, and its temperature, are not adequately accounted for in energy production (Jin et al., 2019) or other production processes. While increasing GDP may reduce poverty in countries by enhancing access to water services, food and improved water management (UNEP, 2019b; UNICEF and WHO, 2017), this comes at a trade-off of degrading natural capital, most severely impacting marginalised people.

Some 2 million tons of sewage and effluents flow into water bodies every day and about one-third of global biodiversity is diminished by degraded freshwater ecosystems, mainly due to pollution (UNESCO and IIWQ, 2023; UN, 2022). Notably, the rich have both a higher impact on pollution and greater access to water, consuming more water per person than the poor (Gupta et al., 2020; López and Palacios, 2014), and have contributed to crossing multiple planetary boundaries (Rammelt et al., 2022).

(iii) Growing urbanisation (55% of people live in urban areas, increasing to 68% by 2050), especially in low-income countries in Africa and Asia (UN, 2018), increases water demand (supply and treatment) as urban residents have higher living standards and aspirations (Kuddus et al., 2020) that also increase their water footprint (Hoekstra and Chapagain, 2006). Unplanned urban growth challenges the effective provision of water, sanitation and hygiene (WASH) services, as informal

settlements may not be recognised by government (Rashid et al., 2018) and, hence, are poorly served with safe water and sanitation services. Non-revenue water impedes proper maintenance of systems and reduces incentives for water supply augmentation. Urban areas also have higher concentrations of grey and black water and, thus, have a greater requirement for water treatment systems, soil sealing and decreasing run-off. As city demographics change, there is also a need for upscaling or creating circular recycling systems (Breitenmoser et al., 2022; OECD, 2016; Filgueira, 2014; Dalton et al., 2008).

Cities are hugely beneficial to humans in the many services they provide and their multiple opportunities for livelihoods. Nevertheless, higher population densities and built-up spaces reduce green areas that contributes to soil sealing with high run-off rates, reducing groundwater recharge, polluting groundwater and negatively affecting human health (Bleischwitz et al., 2018; UNEP, 2016d). Reduced recharge and increased pollution (Bleischwitz et al., 2018) pose health risks to people (UNEP, 2016d). Nitrogenous and phosphorous pollutants can also degrade ground and surface water (Hobbie et al., 2017). City pollution generates about 80% of ocean pollution via river discharge and runoff (Landrigan et al., 2020). Leaking sewerage systems and industrial waste are key challenges (Satterthwaite et al., 2020; Satterthwaite et al., 2019), for ecosystem-based wastewater recycling (e.g. mangroves, wetlands) (Livesley et al., 2016).

(iv) Climate change drives water challenges through extreme weather events (floods and droughts), sea-level rise and saltwater contamination of coastal aquifers, and changes in snow cover, lake and river ice and permafrost. These changes affect groundwater recharge, local food security, hydropower facilities, water-borne diseases and deteriorate water quality. Climate change impacts terrestrial and freshwater species alike, including ecosystems in high mountain and polar regions (NASA, 2022; Satoh et al., 2022; IPCC, 2021; Arfanuzzaman and Dahiya, 2019; UNEP, 2019a; Markandya, 2017), and contributes to higher frequency and magnitude of weather-related disasters (Mohanty et al., 2020; King et al., 2016). According to one projection, by 2070, two-thirds of the global land will experience a reduction in terrestrial water storage, and the land area subject to extreme-to-exception hydrological droughts could more than double (Pokhrel et al., 2021). These impacts are spatially heterogeneous. For example, parts of South America, Mediterranean Europe and North Africa are all projected to suffer unprecedented and extreme drought conditions by 2050 (Satoh et al., 2022).

(v) Underinvestment in water infrastructure is a crucial challenge. Governments have chronically failed to consider non-market values of water and, hence, underinvested in water infrastructure that supports non-market values in both high and low-income countries. This failure has led to a growing financing gap (OECD, 2022; ASCE, 2021). Fewer than 15% of countries have the financial resources to implement WASH plans (WHO, 2019b).

(vi) Technology and innovation are an opportunity but can be double-edged. That is, water pumping technologies increase groundwater depletion (Molle et al., 2018; Shah, 2014) but technology can also improve water access and reduce health risks, and the opportunity costs of time spent on fetching water, particularly for women in low-income places (UNEP, 2016a, 2016b). Irrigation technologies (e.g. drip irrigation) can increase yields (Molden et al., 2003) but frequently reduce blue water return flows to rivers and aquifers. Yet technology can also provide solutions, noting that remote sensing provides estimates of actual water consumption in the most important

blue water consuming sector (i.e. irrigated agriculture) and provides the opportunity for water management to promote more equitable and sustainable outcomes (Perry et al., 2023).

(vii) Inefficiency in how water is allocated, used and consumed presents a huge opportunity (Barbier, 2022). It requires water planning and decision-making that considers the “who, what, where and when” of water through the lens of the price and value of water (Grafton et al. 2023b). This is about establishing a policy and regulatory framework that, in turn, uses instruments that ensure water users are incentivised to conserve water when it is scarce and to reduce pollution and waste, establishing rules and norms such that the public interest trumps vested interests, technologies that increase water affordability and access, removal of subsidies that contribute to water overuse and misuse, water planning that considers and effectively responds to shocks (e.g. weather extremes), among other approaches.

(viii) A key driver is inequality of access which causes skewed water consumption within and across national borders. These have multiple direct causes including large differences in land ownership (Lowder et al., 2021). Countries importing goods made with water rely on virtual water imports, primarily as food (Hoekstra, 2017; Mekonnen and Hoekstra, 2016; Ercin and Hoekstra, 2014; Chen and Chen, 2013). While food-importing countries pay the direct costs of production and transportation, they do not pay for the external costs associated with diminished and/or degraded water bodies, wetlands and riparian zones of depleted aquifers. Thus, virtual water is undervalued, contributing to water scarcity and pollution in virtual water exporting countries (Givens et al., 2019) and, critically, the poor and marginalised bear the greatest burden.

Water inequalities mean that billions of people still lack access to safe water and safely managed sanitation services, and women and girls especially are exposed to health and safety risks during water collection and sanitation (WHO and UNICEF, 2017). In sub-Saharan Africa, 71% of the burden of collecting water falls on women and girls. Girls drop out of school because of domestic work (including fetching water) and many schools do not have menstrual hygiene facilities, thus forcing girls to miss out on education (UN-Water, 2013).



3.2

Impacts and costs of inaction

The **drivers** and **pressures** influence the state of water, which directly and indirectly **impacts** society and the environment.

The **direct impacts** include droughts, floods, shortages and pollution. The **indirect impacts** include effects on access to food security both locally and globally in a trade-dependent world (Mahlknecht et al., 2020; UNEP, 2019a). Impacts also affect livelihoods, infrastructure, the economy and social crises. Livelihoods are also affected by declines in fishery outputs (UNEP, 2019) and agricultural losses (Parsons et al., 2019).

Projections from the GTAP-DynW model commissioned for this report show that hunger progressively worsens towards 2050 (and beyond) (see Kompas et al., 2023). Other indirect impacts include the feedback effects of climate change arising from glacier melting and increased water vapour, thus changing freshwater and ocean ecosystems (UNEP, 2019b; Costanza et al., 2017). Impacts on society are more significant where national social security and safety nets are weak, disproportionately affecting the more vulnerable (e.g. children and women) (UNEP, 2019a: 5).

In sum, a huge opportunity cost is associated with inaction in the face of the world's water crises. Billions of people lack access to water, thus heightening the potential for new conflicts, much greater migration and refugee crises, and increasing food insecurity from too little, too much, or too dirty water (see Figure 3.2).

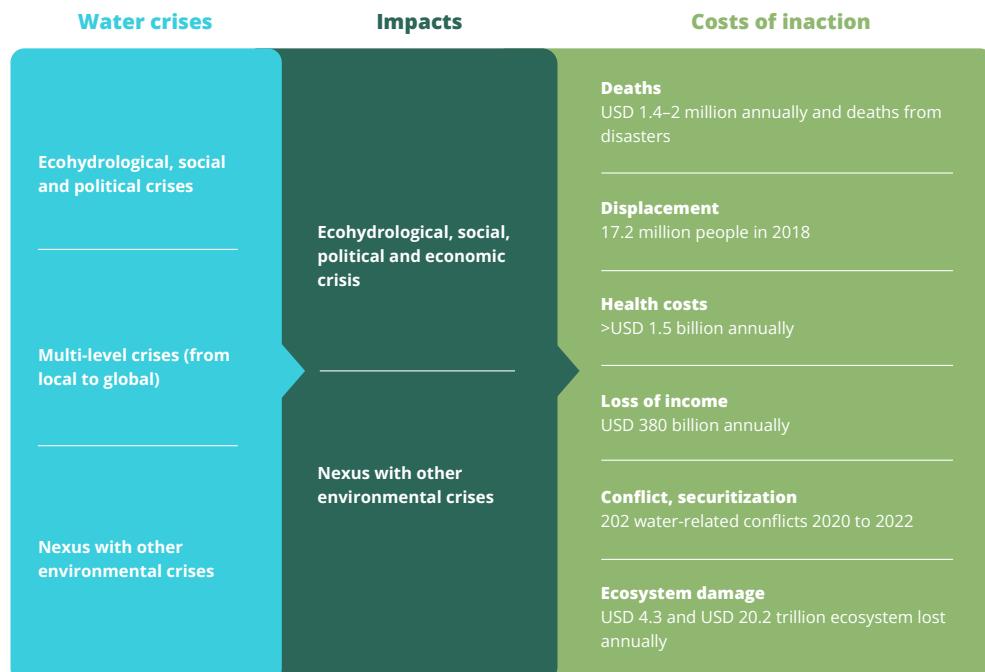


FIGURE 3.2 How water crises are linked to impacts and estimated costs of inaction today
SOURCE: Authors

The immediate global economic losses attributed to climate change in 2020 alone were USD 190 billion (Jones, Guha-Sapir and Tubeuf, 2022), compared to the USD 365 billion lost during the 20th century (Lee et al., 2020). The World Economic Forum concluded that around USD 44 trillion, about half of the global GDP, is dependent on nature (Kousky, 2022). This amount does not include the dependence of the informal sector on nature for its survival. Water-scarce regions like West Asia and Sahel Africa risk up to 6% of GDP losses by 2050 caused by income and property losses, lower agricultural production and health issues (Damania et al., 2016).

Drought is one of the costliest aspects of the water crisis (WHO, 2021). Twelve million hectares of land are estimated to be lost yearly due to drought and desertification (FAO, 2017). The number of people affected by drought by 2050 could be between 4.8 and 5.7 billion (UNCCD, 2022), and by 2030, 700 million people may be at risk of displacement (WHO, 2021). Floods are estimated to have caused 157,000 confirmed deaths globally over the past 20 years (CRED and UNDRR, 2015), affecting countries in both the Global South and North. By 2030, 15 million people and USD 177 billion worth of urban infrastructure could be at risk of coastal flooding and 132 million people and USD 535 billion worth of urban infrastructure are projected to be impacted by river flooding (WRI, 2020).

Climate change will accentuate large flooding events although the frequency of flooding may decline in some locations (Figure 3.3). Coastal locations, with sea-level rise, are particularly at risk to a greater magnitude of flooding when combined with large rainfall events (Douville et al., 2021), which will also change with a warming climate as condensation rates increase. The bio-physical flood impacts depend on multiple factors. These factors include: the surface landscape (e.g. topography), which is affected by land-use change (e.g. forest cover, sealing of surfaces in urban areas), flood-mitigation measures (e.g. storm water infrastructure and catchment management), soil moisture prior to a flooding event (e.g. drier ground can be less able to absorb precipitation from an intense rain event) as well as the volume of precipitation and over what time period it occurs.



Causes of more severe floods from climate change

Flooding presents a hazard but the link between rainfall and flooding is not simple.

While the largest flooding events can be expected to worsen, flood occurrence may decrease in some regions.

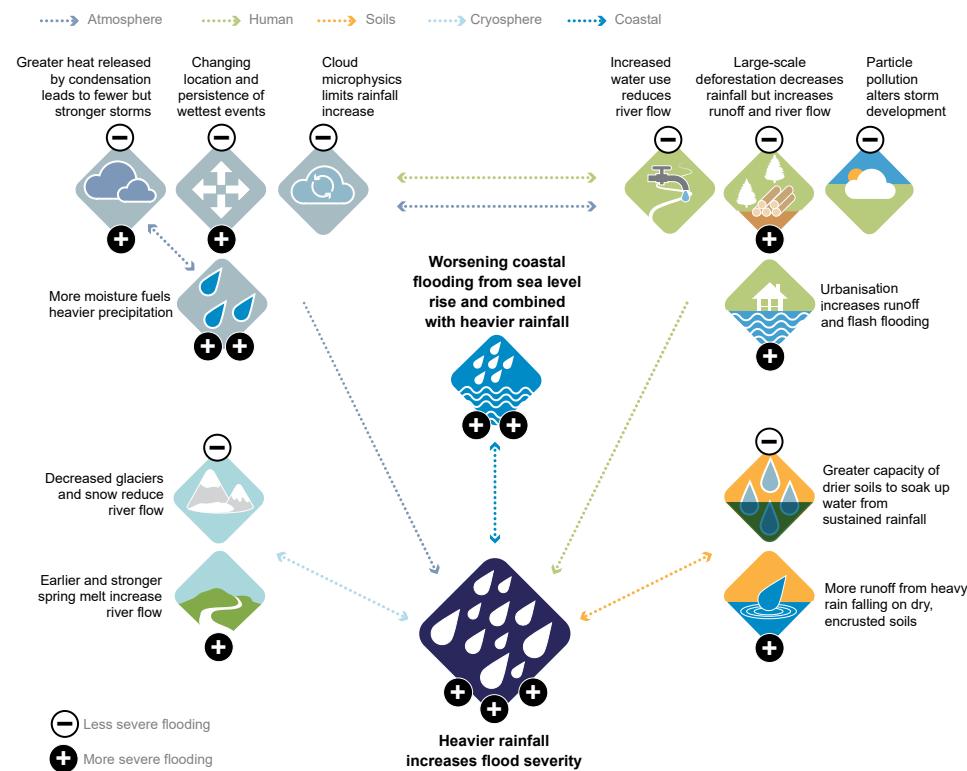


FIGURE 3.3 Causes of more severe flooding from climate change

SOURCE: Douville et al., 2021

Food insecurity affects 720 million to 811 million people globally and is linked to water insecurity (FAO et al., 2022). There are increased health risks, including malnutrition, as grey water is used for irrigation (Grangier et al., 2012). Losses of up to USD 94 billion per year may arise from water insecurity for irrigation (OECD, 2015; Sadoff et al., 2015). The GTAP-DynW model projects that by 2050 the global food supply may decline due to heat stress and water scarcity, from 9.75 million to 9.2, 8.8 and 8.4 million Gcal for representative concentration pathways (RCPs) and shared socioeconomic pathways (SSPs): RCP4.5, RCP8.5 SPP2A and RCP 8.5 SSP3B, respectively (Figure 3.4).

Pollutants reduce available freshwater resources. Over 80% of global wastewater is discharged into the environment without treatment (UN, 2018). At the same time, yearly 300–400 million tons of heavy metals, solvents, toxic sludge and other wastes from industrial facilities are dumped into blue water sources. In agriculture, excessive or inappropriate application of fertilisers leads to run-off from fields, damaging freshwater and coastal ecosystems.

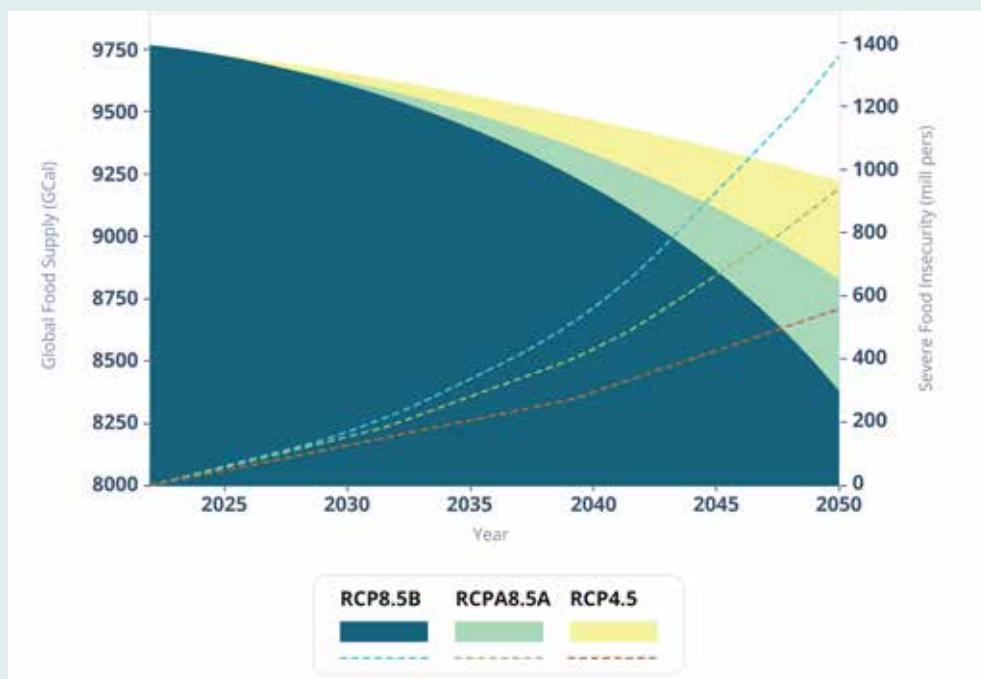


FIGURE 3.4 Global food supply (Gcal) and additional severe food insecure persons (millions) in 2050 for RCPs 4.5, 8.5-SSPA, and RCP8.5-SSPB

SOURCE: Kompas et al., 2023

Diarrhoea from dirty water alone kills 829,000 people annually, which includes some 300,000 children aged under five years (or 5.3% of all deaths in this age group) (Prüss-Ustün et al., 2019). Millions of people need preventative treatment for schistosomiasis (WHO, 2019b) and global economic losses amount to USD 260 billion annually (see Figure 3.5) from poor WASH (OECD, 2021; Sadoff et al., 2015). The spread of water-related anti-microbial resistance (AMR) and AMR diseases costs between USD 1 to 5 billion per year in additional healthcare expenditures (Booher and Mung, 2022). Women are also more likely to be affected by water-related sickness and mortality due to poor sanitation, with estimated costs in 2015 amounting to USD 222.9 billion in income and 0.9% of GDP income losses in some regions (LIXIL Water Aid and Oxford Economics, 2016: 3).

Poorly targeted subsidies and tariffs are biased towards large industries and can create disincentives to invest in unsubsidised water infrastructure, and augments inequities (OECD, 2022). Globally, fossil fuel subsidies were USD 5.9 trillion (equal to 6.8% of GDP) in 2020 and are expected to increase to exceed 7% of world GDP in 2025. Of this subsidy, 8% represents undercharging for supply costs (explicit subsidies — USD 0.45 trillion in 2020 or USD 450 billion), while 92% for undercharging environmental costs and foregone consumption taxes (implicit subsidies). Similarly for water-related investments, subsidies based on service access and connection to delivery systems exclude the poorest within a population and enhance inequity for those who do not have access to “piped systems” (OECD, 2022).

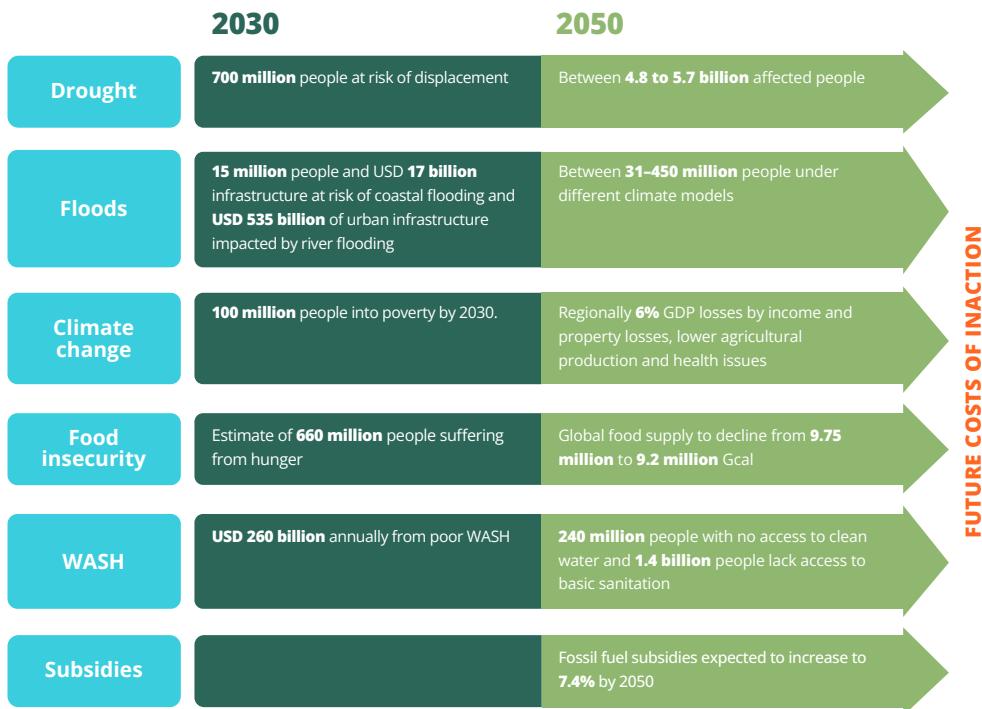


FIGURE 3.5 Future costs of inaction

SOURCE: Authors

Tensions and conflicts continue to occur despite treaties¹ that have been signed over water; the *Environmental Justice Atlas* has 795 entries on water-related conflicts (EJAtlas, 2023). The World Water database also lists 629 conflicts related to water between 2010 and 2019 and 202 conflicts from 2020 to 2022, worldwide. Water shortages can trigger discussions and conflicts about ownership of water and consumption levels on national and internal levels (WRI, 2020). Rivers and aquifers, which spread over and link countries through resource utilisation and co-dependencies, exacerbate tensions (Zeitoun et al., 2020).

Countries with civil crises — Yemen, the Democratic Republic of Congo, Afghanistan, the Bolivarian Republic of Venezuela, Ethiopia, South Sudan, the Syrian Arabic Republic, Sudan, Nigeria and Haiti — are also countries frequently affected by weather extremes, including droughts and/or floods (De Stefano et al., 2017). Extreme weather events (floods and droughts) can result in migration and conflict (Damania et al., 2016) while food price spikes caused by droughts can inflame latent tensions.

River basin disputes and conflicts worldwide could contribute to future water conflicts (Gleick, 2022; Ligtvoet et al., 2018: 82–83; Klare, 2002; Gleick, 1993) or, alternatively and more optimistically, promote greater co-operation (Wolf et al., 2006).

¹For example, 149 negotiated bilateral treaties are signed over bilateral basins; 257 negotiated bilateral treaties signed over multilateral basins; 732 negotiated multilateral treaties signed over multilateral basins; and 195 negotiated basin-wide treaties signed over multilateral basins (Dinar et al., 2019).

BOX 3.1 Global projections of food supply and severe food insecurity in 2050

The GCEW commissioned modelling of the impacts of blue water stress and heat stress on global food production and hunger, with projections to 2050 provided by the GTAP-DynW model (Kompas et al., 2023). GTAP-DynW uses a large dimensional computable general equilibrium (CGE) model, which was developed for the GCEW to project impacts on global irrigated food production and food security till the year 2050 from a base year of 2014. Water stress projections are included via estimates of water supply at the basin level (for 15,006 basins) from run-off values extracted from an ensemble of CMIP5 Global Circulation Models (WRI, 2022) to make projections to 2050. The model results for food supply are for irrigated agriculture (Haqiqi et al., 2016). Heat stress effects are included using shocks on agricultural and labour productivity, adapted from Kompas et al. (2018).

By 2050, the GTAP-DynW model (see Table 3.1 and Figure 3.6) projects that the global food supply may fall by 6%, 11% and 14% on average for the Representative Concentration Pathways (RCPs) and Shared Socio-economic Pathways (SSPs): RCP4.5, RCP8.5-SSP2 and RCP8.5-SSP3 (Carbon Brief, 2018; 2019).

TABLE 3.1 Food supply decreases in percentage by 2050 for two climate change projections

Country/region	Food supply decreases in percentage by 2050	
	RCP4.5	RCP8.5-SSP3
Africa	5.1–6.6	8.2–11
Australia	5.8	14.7
South America*	6.4	19.4
USA	4.8	12.6
China	8.97	22.4
India	6.52	16.1

*Parts of Central America

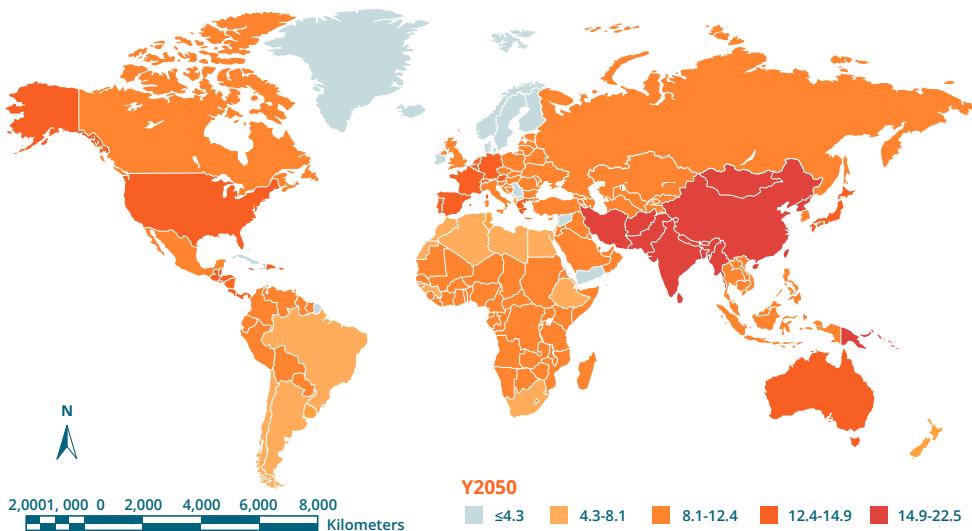


FIGURE 3.6 Percentage reduction in food supply by country from water stress and heat stress for RCP 8.5-SSP3 in 2050

SOURCE: Kompas et al., 2023

Projections from the GTAP-DynW model show that people in severe food insecurity progressively increases towards 2050 (and beyond) and this is principally confined to Africa, parts of western South America, Central America, West Asia and South Asia. Even under the best-case climate change scenario of RCP4.5, most African countries experience an increase in people with severe food insecurity by more than one third. In 2050, for the worst-case climate change scenario (RCP8.5-SSP3), the domestic food supply in many African countries only meets about 40% of domestic food demand (Figure 3.7). Other countries, such as China and members of the Association of Southeast Asian Nations (ASEAN), will switch from being net food exporters to net food importers in 2050. The model's projected number of people in severe food insecurity was converted into the number of additional people, relative to the 2020 base, who are projected to be severely food insecure for RCP4.5, RCP8.5 SSP2A and RCP 8.5 SSP3B (Figure 3.4).

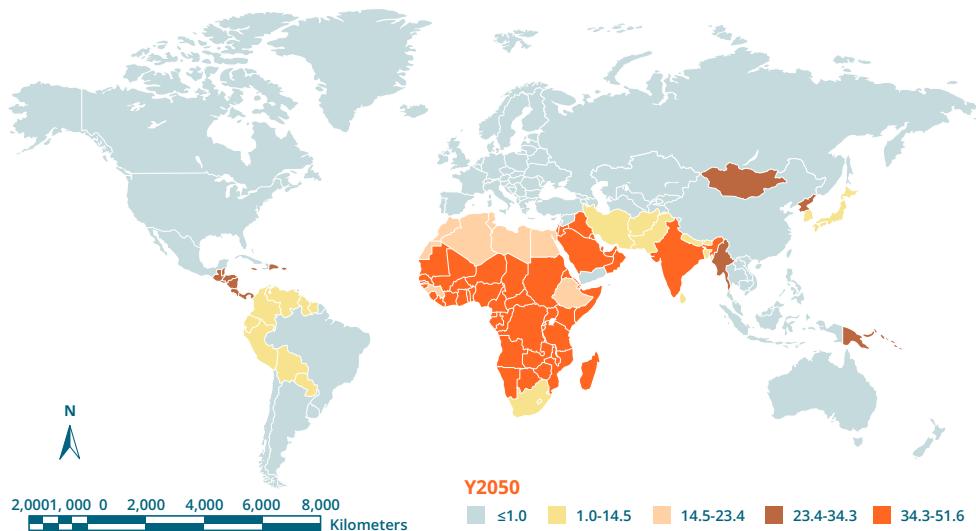


FIGURE 3.7 Percentage increase of persons in severe food insecurity for RCP8.5-SSP3 to 2050

SOURCE: Kompas et al., 2023

The projections of the number of additional people with severe food insecurity by 2050, require caveats. While globally irrigated agriculture is already consuming more than the planetary boundary of blue water for this use, there may be opportunities, particularly in sub-Saharan Africa, Eastern Europe and Central Asia, to use additional water from rainwater harvesting or groundwater, to increase food supplies (Rosa et al., 2021) or, in general, use more green water for agricultural use globally (Rockström et al., 2009). The increase in farm yields from innovation may also be more than sufficient to offset yield decreases (Iizumi and Sakai, 2020) caused by heat stress and water stress (Shamsudduha and Taylor, 2020) and other factors (Scanlon et al., 2007).

3.3

Barriers to improved water governance

Globally, multiple economic, legal and political barriers hamper policy making for sustainable water governance from local to global levels. Path dependencies and lock-in — epistemic, institutional, infrastructural, technological and societal — refer to systems of thinking, and structures that perpetuate unsustainable and inequitable patterns of production and consumption (Seto et al., 2016) and hinder sensible subsidiarity, cross-sectoral coordination and collective action around a new social compact and Our Common Agenda (UN, 2021).

3.3.1 Institutional lock-in

Institutional lock-in hinders the ability to transform water governance. Examples include (i) discursive lock-in, both positive (e.g. the recognition of the human right to WASH) and negative (e.g. prioritising efficiency over equity), (ii) insensitive laws and policies, (iii) economic rules, (iv) existing property rights (e.g. through land, permits and contracts) (Seto et al., 2016; Foxon, 2002), (iv) cemented fragmentation of governance, (v) inappropriate centralisation/decentralisation (e.g. elite capture, lack of allocated resources) and (vi) in many parts of the world, limited agency for citizens, women, children, Indigenous Peoples and local communities and civil society. Change in support of the Global Common Good is frequently hindered by barriers at a national and transboundary scale, which include water rights, disconnect between the geography of authority and catchments, hydro-hierarchies, corruption, narrow interests of states and blind spots (Table 3.2).

TABLE 3.2 Selected barriers for water as a Global Common Good

Barrier	Issue
Water policies and property rights	Policy design that does not account for inequitable pressures on water problems can reproduce injustices and be exacerbated by property rights in water concentrated in a relatively small group of people in both rich (e.g. Australia, USA and Canada) and poorer countries (e.g. South Africa and India) (Bosch and Gupta, 2022b). These include inequalities between settler states versus Indigenous Peoples and local communities, land- versus non-landowners, men versus women, and white versus coloured people. Property rights and quasi-property rights in water, whether historical (e.g. through land ownership) or based on statutory legislation (e.g. through permits, concessions and contracts and allocation arrangement), form a barrier at the local level and influence the flexibility of allocation and reallocation of water (Bosch and Gupta, 2022a; Bosch et al., 2021; OECD, 2015). Weak allocation mechanisms that fail to provide appropriate incentives in response to water insecurity, and drivers and pressures, are increasing water misallocation while capacity and financial constraints limit the alternative policy options (e.g. volumetric water pricing).
Management scale	Water bodies do not adhere to geographic boundaries of nations or communities, leading to mismanagement, exploitation and tensions amongst water users (Romano and Akhmouch, 2019).
Hydro-hierarchies	Vested interests and hidden agendas of different actors and large investments are prone to rent-seeking behaviours, regulatory capture and corruption (Grafton and Williams, 2020; Lele et al., 2018; Molle, 2009a).

Corruption	Water laws and allocation are based on the preferences of influential private enterprises in return for political support and funding (McCulligh, 2018), resulting in over-extraction by some at the cost of others (Tetreault and McCulligh, 2018). Expediency and speed are used as covers for corruption to push through plans and infrastructure that benefit the influential rather than all (Wade, 1982) and obscure the truth (Grafton et al., 2020).
Interests of donor states	Discourses such as water privatisation marketed by donor states, without understanding local conditions, have been differentially translated in the policies of low-income and transitional countries (Hall et al., 2005; Hall and Lobina, 2004; Lobina, 2005). This fails to account for the local context (Taylor et al., 2019). Inconsistencies and a lack of bespoke approaches mean that broad principles on water governance (e.g. OECD, 2018) are not always applicable (Taylor et al., 2019).
Blind spots	These are persistent errors, misunderstandings or misrepresentations about how to respond to key water challenges. They include confusions over water use (abstraction, withdrawal, extraction) vs. water consumption (evapotranspiration), and the misconception that an increase in water-use efficiency in irrigation generates water savings when it, typically, increases water consumption (Grafton et al., 2018; Perry et al. 2023). Blind spots also include inadequate recognition of ecosystems such as wetlands as being central for water availability, quality and flow regulation.

3.3.2 Infrastructural lock-in and vested interests

Water supply infrastructures are often separated from sanitation services. This is because sanitation is, typically, more expensive and less of a political priority, and cost recovery is more difficult (Isunju et al., 2011). The estimated global costs to renew water infrastructure of supply and sanitation services amount to USD 6.7 trillion per year by 2050 (about 7% of global GDP in 2020); these costs rise as the costs of maintenance, repairs and upgrading are pushed into the future (Romano and Akhmouch, 2019).

In the 1990s, the rise in private sector involvement in the water sector was welcomed, but since the 2000s there has been a global trend to re-municipalise water services, because the multiple modalities of private sector engagement in the water sector have not generated the expected benefits (Cumbers and Paul, 2022; McDonald, 2018). Reasons for the re-municipalisation of water services include poor performance of private companies, deteriorating quality of provided services (Kishimoto, 2019: 52), underinvestment, a failure to expand the serviced network, failure to comply with promised infrastructure improvements, poor service quality, lack of transparency, inadequate cleaning up of water and overpriced services and corruption (Bel, 2020).

Hydro-hierarchies refer to the unequal distribution of power in relation to decision-making around the “who, what, where and when” of water. In many countries, decisions about investment in water and regulations about how water is governed are made by public servants (Molle et al., 2009) but there are multiple influences and redirections that sway these decision-makers away from the common good. Inertia to reform in the public sector and lock-in of fragmented governance is exacerbated by lobbying from vested interests of decision-makers to resist change (Roberts and Geels, 2019; Pahl-Wostl, 2017) that has big negative impacts on economic performance (Olson, 1996). Institutionally embedded corruption and rent-seeking behaviours, specifically in the water sector, not only worsen vulnerabilities and poverty but also erode natural ecosystems. Dasgupta (2021) observed the importance of eternal vigilance, rather than ad-hoc measures, to ensure decision processes are “tolerably clean” to reach the sustainable development goals and to benefit the common good.

3.3.3 Technology gaps

The GCEW will undertake a detailed review of water technologies in 2023–24. A preliminary review highlights that technologies and infrastructures for water augmentation are challenging because some technologies: require huge amounts of materials and energy (e.g. desalination); lead to large amounts of waste (e.g. concentrated brine, chemicals); change water flows (e.g. dams, water transfer plans, air to water technology); change access rules to water (e.g. large dams); or violate international law (e.g. geoengineering of clouds) (Reynolds et al., 2022). Although many of these technologies are seen as a solution to water scarcity, they may also create new problems that require mitigation. For example, access to water pumping technologies has made groundwater much more accessible and allows landowners to increase water withdrawals for irrigation (Bassi, 2014; UNEP, 2019b). By contrast, remote sensing and “evapotranspiration management” has helped to stabilise and restore aquifers in Northern China by measuring and controlling water consumption at a farm, project and basin level. “Flying Sensors” complement satellite data and are used by individual farmers to determine locations that have too much or too little water (Perry et al., 2023).



3.3.4 Behavioural “lock-in”

Societal lock-in affects the ability to transform water governance. Often, water management takes place at the community level, and so social structures and norms have an important influence (Nhim and Richter, 2022) on processes and outcomes. Social structures affect water allocations (and reallocations), priorities for investment and planning and people, and the connections people have through infrastructure, investments and shared tasks (Nhim and Richter, 2022; Hogeboom, 2020). Social structures and norms also contribute to behavioural lock-in (positive and negative) that affects (positively and negatively) water governance. A “siloeed approach” to water governance is common across public sectors and businesses creating a separation in understanding of causes, effects and feedbacks. Today, while the interconnections are acknowledged, actions remain bound by the silos through which we think about and manage water (Dunn et al., 2017).

Failure to understand or to include differences in knowledge systems of water governance reinforces inequalities (Taylor et al., 2019) because knowledge systems shape how water is valued and managed (Grafton et al., 2023). Indigenous perceptions and values of water are founded on long-standing cultural values rather than, principally, market values (Jackson, 2018; Mehltretter et al., 2023). Failing to understand many forms of Indigenous knowledge disrespects land and water custodians and increases the risks of mismanagement because some Indigenous communities have thousands of years of experience successfully managing riparian systems, including during mega-droughts. Many cultures have faith-based approaches and practices to water that advance context-relevant solutions (Laster and Livney, 2009; Naff, 2009).

Poverty is another key institution-induced barrier. This is because a lack of economic resources is often a barrier to households who are unable to pay for WASH utilities or connection costs, especially in the Global South (Boakye-Ansah et al., 2019; World Bank, 2015). In the Global North, for example in the United States, consequences of extreme weather events are borne disproportionately by the poor (Rosane, 2022). Historic racism means poorer communities predominantly inhabited by people of colour with a migrant background are most at risk as they, typically, live in locations more prone to flooding (Rosane, 2022), while the benefits of infrastructure investments are unevenly shared among ethno-racial groups (McDonald, 2023).



3.4

Transformational and transitional pathways

Most communities and countries living through the water crisis are taking multiples actions to mitigate risks yet change takes time and there is a constant challenge to avoid unsustainable pathways (Figure 3.8). Transitions towards sustainable uses of water vary for different communities depending on where the change is occurring (local to global), context (urban, rural, forests, industry) and history. Nevertheless, a few general principles and conditions of change apply.

To illustrate the many possibly pathways, we note that the first transition (e.g. water, energy) in Figure 3.8 considers what “systems thinking” means for the current governance structures. This means identifying where decision-making is best placed, what outcomes must be prioritised, who should be responsible and accountable, and how risks should be evaluated. A systems view must also consider all the multiple values of water, (e.g. non-market values and market values) that are relevant for policy makers, local communities and nature. A participatory approach is one option for integrating values and serve as a “bridge” to different knowledge(s) (Mehltretter et al., 2023). Another approach is, where appropriate, to build on “citizen science” to bring together decentralised and diverse thinking and observations (Buytaert, et al., 2014). A possible second transition point is to “experiment” at broadening knowledge bases to enable creative solutions such as with Indigenous communities (Davies et al., 2021). A third transition point could, in relation to infrastructure (grey, green and soft), be about retaining flexibility and options in response to uncertainties (e.g. induced by climate change). Overlaying these possible transition points is the need for ongoing inclusion in decision-making processes and continuous vigilance against corruption and rent seeking that can easily change the direction of development towards unsustainable pathways.



FIGURE 3.8 Future pathways for a safe and just water future
SOURCE: Authors

04

How? Economics for the Common Good

A safe and just framing for water complemented by systems thinking (water-energy-food and environment nexus) is needed to create a new framework on the economics of water. This framework must rethink governance; reprioritise values, valuation and investments and, thus, reshape states; reshape markets; redefine water and possibly land ownership; and re-engage with the connections between the economy, the environment and water use and consumption.

4.1

Water cycle as a common good

4.1.1 A common good approach to water

Achieving a just water future requires collective action, noting that water has multiple forms: it can be a public good (e.g. water sanitation), a private good (e.g. bottled water), a common-pool resource (e.g. water in an aquifer) or a club good (e.g. community-based irrigation scheme). If we restrict our economic view of water to the realm of public goods alone, this inhibits a more proactive response to water challenges by, for example, limiting government policy to fixing market failures and disincentivising private sector investment.

A new framework must go beyond reactively “fixing” or “correcting” market failures to proactively regulate and shape markets and reshape states (Grayling, 2020). While correcting market and government failures is valuable, it overlooks the underlying drivers, pressures and barriers to change, that need to be understood, and responded to, to overcome the water crisis and avoid the costs of inaction. Achieving a just water future can be supported by a mission-oriented approach to economic thinking. This approach reorients the economy and society around achieving ambitious missions with a demonstrable and accepted public value and purpose.

A mission-oriented approach to market shaping begins by asking, “What is the problem we want to solve?”, framed as a goal to be achieved through investments in sectors and collaborations within individual projects (Mazzucato, 2021). Importantly, missions for the common good should be bespoke and avoid a top-down approach to aid the inclusion of justices and respond to the underlying drivers and barriers (Mazzucato, 2018). Setting actions with targeted, measurable and time-bound goals is key to delivering a successful and equitable global water mission within the constraints of water and planetary boundaries, noting there is no global institution devoted to such a mission. This orientation requires adaptable and flexible strategies that can be continuously improved through trial and error, through active citizen participation, grassroots experimentation and cross-sectoral governance (Mazzucato and Dibb, 2019).

Missions are a framework that shapes economic policy in an outcomes-oriented way in the service of the common good. They create public value with a public purpose (Mazzucato and Ryan-Collins, 2022). In turn, this requires a proactive public sector to set a direction, and economic actors to collaborate and innovate to solve societal problems of fair water access. Guided by a common good approach, missions help deliver solutions to challenges that require economy-wide coordination and financing across many years. That is, missions capture what needs to be done across multiple sectors and actors to achieve a particular goal to change or reorient production, distribution and consumption patterns towards socially desirable goals.

Whether designed by local, regional, national or international governing bodies, missions must be deliberative. A mission-oriented approach provides an interface between innovators, the public sector and the whole of society to catalyse the distributed intelligence of the private sector and individual citizens (Mazzucato and Kattel, 2020) to anticipate costs of inaction and compounding injustices. Missions for the common good should put citizen participation at the heart of govern-

ment actions and connect broader policy measures to issues that matter to people, to mitigate the influences of vested interests and help decision-makers understand policy challenges from multiple perspectives (Mazzucato, 2021).

Like the common good, achieving a safe and just water future is an outcome, and governments must design policies to deliver on that outcome. This process brings together collective intelligence and access, as well as the design of the interface to empower bold action, embedding collective principles at the heart of water policy. Embedding a common good approach into water missions can help steer policy to deliver more equitable outcomes. For example, a national mission aimed at providing fresh water and sanitation for all could deliver the clarity and focus into local, regional and national cooperation networks and institutions, serving as a catalyst to design collective and justice-related principles into investments and institutions.



4.1.2 Water scarcity requires water sharing

Growing per capita water scarcity requires sharing of water in a just manner if "Water for All" is ever to be achieved (Gupta and Lebel, 2010). Under business-as-usual water management, fairness can be obscured through the priority given to efficiency, and justice becomes a rhetorical statement (Zwarteveld and Boelens, 2014). Severe water pollution and extreme weather events can induce such scarcity where freshwater is contaminated by polluted water. Climate change and land use patterns have seriously affected the predictability of rainfall, creating additional justice challenges. The current instruments used for water sharing need to move from incremental piecemeal approaches to responding to the fundamental drivers of the water crisis.

A just process would determine who gets what water, when and where (Syme et al., 1999). It needs to be sensitive to scale and context (Zwarteveld and Boelens, 2014) and account for inequalities in decision-making (Hartwig et al., 2021) and means; not just the ability to pay. This is different to business-as-usual where markets, in the absence of appropriate policies and regulation, at best, have provided "thin market justice" (Ehresman and Okereke, 2015). For example, Australia has one of the most developed formal water markets in the world within its Murray-Darling Basin (Grafton and Horne, 2014; Wheeler, 2021) and has also established water pricing for urban households that recovers both operating and capital costs (Productivity Commission, 2021). Yet, First Nations control less than 1% of the water rights within the Murray-Darling Basin (Hartwig and Jackson, 2021) and many remote communities across Australia lack drinking water that meets Australia's Drinking Water Guidelines (Wyrwoll et al., 2022). That is, water markets and water pricing alone cannot deliver water for all, and that is why a justice lens is needed. How this should be done depends on the context, but Figure 4.1 (Gupta et al., 2021) illustrates how goals (e.g. local, global) and actions (e.g. incremental, transformational) need to be aligned, noting that full recognition is needed as to how injustice is perpetuated (Harris et al. 2017; Hartwig et al. 2021).

Transformative change is needed because, as Dasgupta (2021) has highlighted and is outlined here in Chapter 2, business-as-usual has failed to prevent the massive deterioration of the biosphere and expanding economic and social inequality. Halting this decline demands Earth System Justice that includes an intergenerational, intra-generational and inter-species approach to governing water (Gupta et al., 2023). Standard economic instruments respond to declining water quantity

and quality and the proximate causes but without a proper understanding of underlying drivers and, typically, without a justice lens. The scale of the water crisis is such that governments cannot wait for markets alone to deliver a safe and just water future as market mechanisms alone cannot respond to failures at multiple levels of water governance. Instead, governments must work with other economic actors (civil society, communities and businesses) to proactively invest in and shape solutions and develop a new framework to overcome water-related challenges.

An Earth System Justice approach, involving an iterative local to global standpoint, has three starting points. It chooses transformative justice over incremental justice, as the latter will only reproduce injustices (Gupta et al., 2023). It adopts recognition justice, which recognises the views of others and considers their multiple values (Box 4.1). It builds on epistemic justice (Fricker, 2007), where knowledge systems from different parts of the world are equally valued. The implementation of these justice concepts (transformative, recognition, epistemic) face three key challenges. First, is the challenge to identify multiple values and valuations to respond effectively to the water crisis. Some of these values are critical for defining the regulatory space and others for redefining the “what and how” of policy instruments. Second, is the challenge to ensure water is used and consumed in ways that do not compromise Interspecies and Earth system stability. Third, is the challenge to promote intergenerational justice between past and present generations, and present and future generations, while accounting for historical injustices (e.g. climate impacts on current water crises) and intragenerational justice between countries, between communities and between individuals.

Conservative/incremental



FIGURE 4.1 Possible justice approaches to respond to the water crises
SOURCE: Building on Gupta et al., 2021

Operationalising justice requires consideration of both ends and means (Gupta et al., 2022b). The three ends include: (i) meeting human rights and the social goals of the SDGs through minimum access rights to water for WASH, food, energy and infrastructure and livelihoods; (ii) ensuring equitable sharing of the remaining water between uses and users at multiple levels of governance; and (iii) reducing harm through adopting water limits as well as water-related standards from the local to the global level. The two means include: (i) responding to the drivers of the water crisis (e.g. polluter pays principle, do-no-harm principle); and (ii) overcoming the barriers to improved governance (e.g. developing rules of liability for harm caused to others; rules about the priority of use and equitable sharing of water).



4.1.3 Valuing and pricing water for equity, efficiency and sustainability

Well-designed economic policy instruments enhance efficiency and allocate (reallocate) water by signalling the right investment time (e.g. to augment water supply or to mitigate pollution) and fully account for the costs that water uses (and users) impose on others (Wheeler et al., 2023). In practice, poor design and implementation, inadequate regulation and lax enforcement result in inefficient water allocation, finance and inequitable access to services, or exposure and vulnerability to water risks. Poor policy design also discourages (private) finance and increases pressure on public funding.

The value of water is the benefit (direct and indirect) to water users from access, use and/or consumption of a given volume of water at a particular place and time. A key operational tool for water allocation and reallocation are market values (e.g. irrigated commercial crops) of water that are much more readily quantified over non-market values. Thus, when non-market values are not estimated, they are neither prioritised nor managed. This prioritisation of market values over non-market values prioritises certain types of investments (e.g. grey infrastructure with a high financial return) but can hamper progress on the SDGs that connect to nature and ecosystems (UN 2021; IPBES, 2022). That is, when the full economic costs (including external costs) are not considered, this contributes to the degradation of water resources (Garrick et al., 2017). Notably, many aspects of nature related to freshwater are not, or are only partially, valued in the marketplace (e.g. rivers and lakes). This means the social and environmental benefits of investments in the conservation of nature are not properly evaluated. Yet, natural systems generate multiple benefits in terms of ecosystem services (e.g. climate regulation) and economic value (Colby, 1989; Dupont and Adamowicz, 2017).



Non-market valuation methods have been developed and improved over time (Champ et al., 2017; Young and Loomis, 2014) but have seldom been used when deciding water allocations. Such decisions frequently require quantification of trade-offs and opportunity costs and benefits. For example, a full assessment of the benefits of minimum environmental flows against the market benefits of irrigating a crop (Akter et al., 2014), which are often decided based on monetary assessments, must also include non-market valuation. Only when multiple water values (economic, cultural, ecological and socio-political) are incorporated into planning and decision-making will actions change (Dasgupta, 2020; IPBES, 2022). By contrast, disregarding non-market values of water (e.g. cultural, ecological, socio-political), contributes to shortcomings, including inequities, which undermine sustainability. Non-market valuation methods must also consider whose values are valued (UN, 2021), consider trade-offs and reconsider broader environmental value beyond how it is valued by humans.

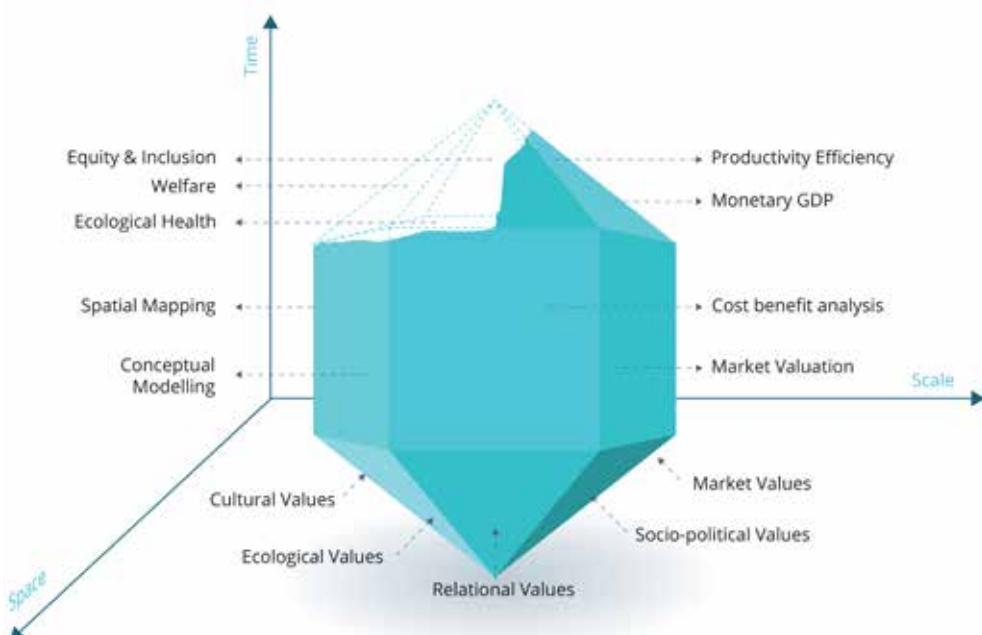


FIGURE 4.2 The Water Diamond: Multiple values and methods of valuing water
SOURCE: Authors

The challenge and choices available are highlighted in Figure 4.2 where the underlying values (e.g. market values) help to determine the methods of water valuation (e.g. cost-benefit analysis). A new framework for the economics of water expands the values typically considered under business-as-usual depicted on the right-hand side of Figure 4.2. With a new framework, additional values (e.g. cultural and relational values) are included, and the water valuation tools and practices (e.g. spatial modelling) (UN, 2021) are expanded. Importantly, water-related valuation for decision-making must include all water values and encompass a wide range of valuation processes such as qualitative, quantitative, monetary and intangible values (WBCSD, 2015).

BOX 4.1 Braiding water knowledge and values

The plurality of water values offers opportunities to “braid together” different knowledge systems (McGregor, 2021), promoting collaboration built upon mutual respect and shared interests. When braiding, each knowledge system must be respected, and its individual integrity maintained. Multiple knowledge systems can create new understandings of water, without diminishing or prioritising any one set of values, worldviews and knowledge (Mehltretter et al., 2023).

Mehltretter et al. (2023) outlines four key principles for braiding Indigenous and Western knowledge systems, called EAUX (the French term for waters). The “E” refers to equity, or the importance of valuing different ways of knowing and challenging colonial power structures and hierarchies. The “A” is for “access”, which is attained when collaborative projects respect data sovereignty and cultural and intellectual property. The “U” is for “usability”, the principle that the partnership will benefit Indigenous Peoples and respond to community needs. The “X” represents the importance of continuous partnership “eXchanges” between parties (Mehltretter et al., 2023).

Knowledge braiding is not without its challenges. Cross-cultural, methodological, institutional (rules) and social-political enablers and constraints influence the context and environments for braiding. Nevertheless, there are successful examples of how braiding can be achieved. For instance, The Chippewas of Nawash Unceded First Nation (CNUFN), called Neyaashiinigmiing, meaning “point of land surrounded on three sides by water” located in Georgian Bay, southern Ontario, Canada, developed a source water protection plan based on Indigenous knowledge from Anishinaabe teachings of Elder Joanne Keeshig (Marshall et al., 2020) and other knowledge(s). Their approach aligned with Anishinaabe values and worldviews; that is, water is sacred, and water is connected to everything (Mehltretter et al. 2023). Mehltretter et al. (2023) provides methods and exemplars of braiding knowledge systems throughout the many stages of diverse water projects, from fisheries management to climate change adaptation.

Setting a safe and just water future as our goal and redesigning the economics of water around the concept of a global common good has considerable implications on the pricing, accounting and financing of water, as well as on the governance of partnerships and trade arrangements.

A water price is the amount paid (typically in monetary units) by a water user (individual, household, community, business, etc.) for a given volume of water of perceived quality at a particular place and time. Sufficiently high enough water prices signal water scarcity and inform (and eventually change) the behaviours of water users, especially for high-value and low-volume water uses such as household drinking water. Water prices can support revenue generation and contribute to financing water services and investments. The direct costs of water use include fixed capital costs and also variable costs that depend on the volume of water treated and delivered. The indirect costs of water use include the external costs that arise when water use and/or consumption negatively impact others and these externalities are not borne by those causing these costs.

In almost all countries, the price of water in the formal water system is well below the total cost of water production and distribution, not including the opportunity costs of the water supply. Consequently, the residual cost burden of many water services is transferred either to taxpayers and/or those paying more than the actual cost of water services through cross-subsidisation. Those without access to formal or piped water systems and who access their water themselves or through water vendors can pay several times more per litre than consumers in centralised, piped systems (Kjellén and McGranahan, 2006).

Typically, transfers or subsidies are provided for water services that principally, if not exclusively, benefit water consumers connected to piped water systems while those with the least (or no) piped water supply access, typically, get the lowest, if any, subsidy (Komives et al., 2005; Whittington et al., 2015). Thus, the 30% of the world's population without access to safely managed drinking water (WHO et al., 2022), including in rural areas (Hope et al., 2020), are typically not direct beneficiaries of water subsidies (Komives et al., 2005; Banerjee et al., 2010; Angel-Urdinola and Wodon, 2012; Barde and Lehmann, 2014).

Water subsidies may also be provided indirectly to water users. For example, subsidies for energy use in agriculture, such as in India, incentivise greater water use, thus leading to aquifer depletion (Chindarkar and Grafton, 2019; Sayre and Taraz, 2019). In general, the scarcer the water of a desired quality, the larger the costs of water use (direct and indirect), the more valuable water pricing is as a tool to allocate and reallocate water across competing uses. Yet, this comes with issues of water affordability, feasibility and justice.

Affordability is a challenge with pricing water for agriculture in the Global South, where a high price for water may reduce the net income of low-income farmers, for whom water use is, typically, high volume with relatively low value added. Unlike water supply for households, which is a private good (consumption is rivalrous and exclusion is complete), water supplied through irrigation is frequently a club good (consumption is rivalrous but only when there is "crowding" or too many "members") provided through shared irrigation infrastructure. Thus, while pricing a private good alone can result in an efficient allocation, for a club good an additional instrument is, typically, required such as a restriction on membership, or possibly a limit on use per member, to account for crowding (Sandler, 2013).

Another difference with irrigated water supplies is that the water is seldom provided on demand, or delivered volumetrically, and surface hydraulic infrastructures frequently do not supply water in a precisely regulated way as occurs in water supply for households. Consequently, irrigated water is supplied to farmers when it is available rather than when farmers would like to use it (Molle, 2009b). This means that farmers who may have little or no decision-making power about water deliveries (when and how much water is supplied) are, understandably, reluctant to pay for an inadequate water supply service (HLPE, 2015).

Direct and indirect water supply, use and access costs differ across space and time. Consequently, an economically efficient water price that recovers the direct costs of water supply and mitigates the external costs of water use and consumption must also vary across space and time. Multiple options exist for pricing water (see Figure 4.3). A water tariff may include a fixed charge independent of water use and a volumetric price, which is the unit price for a given volume or the

entire volume of the water used. To effectively charge a volumetric price for water, there must be a method of either metering or estimating the volume of water used (Bassi and Kumar, 2012). In the absence of subsidies to water suppliers, the water tariff must cover all the direct costs of water supply.

Effective water pricing creates a virtuous circle to respond to water scarcity (Barbier, 2019). In relation to household water services, it should: (i) Support full cost recovery (in which the economic costs of the water supplied are paid for) in ways that provide an incentive to maintain or invest in water infrastructure; (ii) Deliver an efficient water price (price is equal to a transparent marginal cost, including marginal external costs of supply); (iii) Promote equity (as many people as possible, regardless of income or circumstances, have their basic water needs met); (iv) Incentivise water conservation while protecting their basic water needs (Grafton et al., 2023); and (v) Protect ecosystems on which water availability depends. Despite these principles, a recent global study of water supply costs and revenues of the water services sector found that only 35% of water suppliers could cover their direct operating costs from their revenues, and only 14% of their direct operating costs and capital costs (Andres et al., 2021).

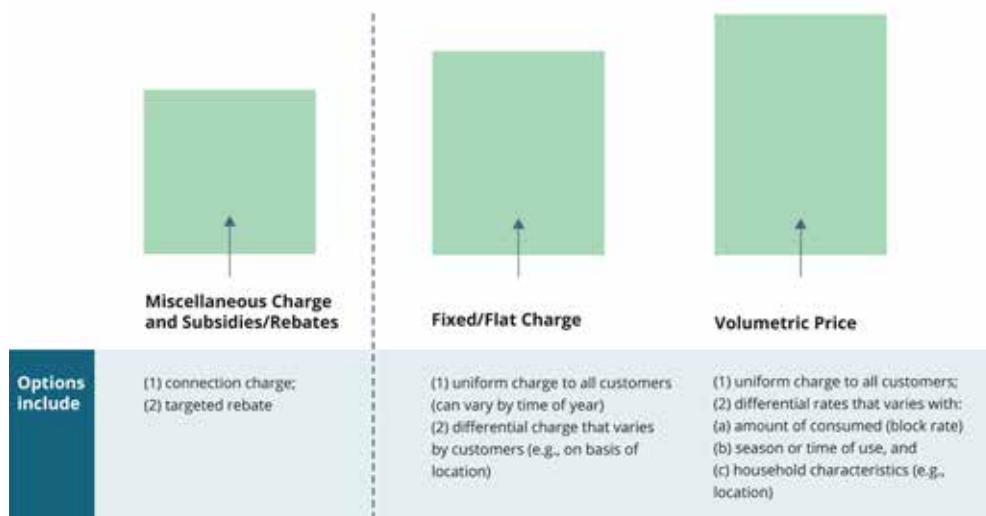


FIGURE 4.3 Water tariff and prices

SOURCE: Grafton et al., 2020: 95

To ensure water users are incentivised to internalise the direct and indirect water costs, household water prices should change as costs change. Typically, surface water supplies are lower in periods of drought, and water demand is higher. Household water consumers can be charged a higher volumetric price to signal increasing water scarcity. How much households reduce their water demand due to a higher price depends on the price elasticity of water demand (García-Valiñas and Suárez-Fernández, 2022). For households with piped water, the price elasticity is generally low and price inelastic. This low-price elasticity means that the percentage reduction in demand is less than the percentage increase in the volumetric price. Consequently, substantial increases in volumetric water prices may be needed to induce significant household water conservation. Thus, water users or water utility regulators should consider reducing fixed charges of low-income households as volumetric prices rise (Grafton and Ward, 2008).

When setting a water price, key questions include: Is its primary purpose for cost recovery? Or is it for water conservation? Or is it to ensure that everybody can access water for household and agricultural purposes? As highlighted by the Nobel-Laureate Economist, Jan Tinbergen, each objective requires its own instrument; thus, more than one economic instrument (i.e. a water price) is, typically, needed to respond to multiple objectives. How water prices are determined must also consider the context, noting that pricing water for households as a private good is not the same as pricing water for irrigators, which is, typically, a club good.

Multiple options exist for “pricing water” to irrigators, including surface area or crop-based charges, and fees to cover the costs of infrastructure, and operations and maintenance costs. Such pricing models, however, provide no marginal incentive to reduce water use by irrigators. Alternatively, a sufficiently high enough volumetric price would reduce water use, but would also require the appropriate water delivery infrastructure, water meters, monitoring of compliance, and the capacity to control the water supplied to irrigation infrastructure.

A volumetric water pricing approach for irrigation is challenging, even in high-income countries, because the level of the volumetric price to reduce water use may be difficult to implement politically, and the price would also need to vary if the goal is to have water use vary with water availability. If reduced water use and consumption are the key priority, quantitative limits (e.g. water entitlements) on blue water use, that vary with water availability, have been shown to be more effective than establishing a market-clearing irrigation volumetric water price (MacPhail et al., 2012; Molle, 2009b). When water use entitlements are tradable, the interactions between buyers and sellers, influenced by the overall cap on water use and which should vary depending on water availability, sets the market water price rather than a regulator or water supply authority. An effective water market, however, requires proper regulatory oversight and monitoring including water audits of the impacts of water trading, use and consumption.



4.2

A new framework for the economics of water



4.2.1 Shaping effective and equitable water markets

Critical to tackling water-related challenges is a new, more symbiotic relationship between different economic actors — a dynamic, mutualistic relationship characterised by shared goals that maximise public value and the common good, prioritisation of stakeholder value on the part of willing businesses and co-investment in technology, skills and infrastructure. This requires water markets to be “shaped” in ways that ensure that the outcomes of investment, innovation and collaboration are more equitable and sustainable.

Markets can incentivise water users to respond to increasing water scarcity (Grafton et al., 2011). Informal water markets between individuals exist almost everywhere in the world, including water vendors in many cities in the low-income countries (Bhatia and Falkenmark, 1993; Wutich et al., 2016) that provide a valuable service; although, typically, their water is much more expensive per litre than what is supplied through centralised piped systems. Formal water markets with well-developed regulatory controls, formal contracts of exchange and transparent water prices of the water traded are limited to a small number of middle- to high-income countries (e.g. Australia and western states of the USA) and for water quantity. In these formal water quantity markets, water is traded through brokers/intermediaries or via formal exchanges, and prices may fluctuate daily, depending on available supply and demand factors.

Markets for water quality are much more limited, with only a few successful examples of trading, such as in salinity credits in the Hunter Valley, Australia (Olmstead, 2010). By contrast, water pollution taxes are much more common, yet many of the improvements in water quality, at least in parts of the Global North such as the EU, have occurred because of water quality standards (Steinebach, 2019). Water pollution taxes do not necessarily reduce pollution. For example, in Bangladesh, non-compliance to regulations is easier for businesses as water pollution fines are levied arbitrarily, and when levied, are less costly for companies than reducing pollution (Haque, 2017).

Formal water markets may include short-term or temporary transfers of water and/or permanent transfers of water entitlements or rights and, typically, include an overall cap that is the sum of the available water rights. Ideally, this cap should not be fixed but change with water availability. Well-designed marketplace rules and due diligence encourage water trade participation, reduce strategic gaming (Sovacool, 2011), and improve efficient and equitable allocation (ACCC, 2021) if equitable allocations schemes are built that recognise the rights of Indigenous Peoples and local communities. Appropriate regulatory oversight and consideration of justice in water market design is essential. Properly designed water markets can improve the welfare of both buyers and sellers of water or water rights and allow for water to be reallocated to higher market value uses (e.g. water trades from pastoralists to grapegrowers).

Like all other markets, water markets need to be regulated with oversight to mitigate or overcome inequitable or unjust initial allocations of water rights, market power, and imperfect and different information across those trading water (Bauer, 2015; Wheeler, 2021). Importantly, non-market values and equity needs are, at best, only partially included in water markets but should be accounted for when determining the rules about trading and type of water use (Grafton, Horne and Wheeler, 2022). Water trades within formal water markets also need effective institutions (e.g. monitoring and compliance) and hydrological rules (e.g. water balance of a catchment).

Rapidly developing formal water markets need to learn from the successes and failures of existing markets (Grafton and Horne, 2014). Without careful design and regulatory oversight, markets will fail to deliver efficiency, equity and sustainability (Maestu, 2012; Young, 2014). This idea applies equally to carbon markets, especially concerning Clean Development Mechanism (CDM) projects that, in some cases, have failed to deliver on their carbon mitigation commitments (Macintosh et al., 2022) and may have worsened sustainable development outcomes (Olson, 2007). In the case of water, markets should be designed to: ensure fairness in the initial allocation of water rights and, significantly, not disadvantage marginal communities; promote sustainable (and adaptable) water use; include water accounting and auditing for hydrological integrity of water trades; incorporate measuring and monitoring of water use, availability through ecosystem protection and compliance with water use limits; and consider non-market values, including cultural and environmental justice values, not just market values (Wheeler et al., 2023).



4.2.2 Increasing, innovating and scaling up finance for water

Finance has featured prominently on the global water agenda for two decades. In 2003, the Camdessus Report documented the financing gap and called for a doubling of finance (Winpenny, 2003). Later, Hutton and Varughese (2016) projected that the current level of finance for water should be multiplied by three to achieve the ambition of SDG 6 related to access to safely managed drinking water and sanitation. In 2021, UN Water assessed that achieving the SDG global targets 6.1 and 6.2 by 2030 required a fourfold increase in the current rate of progress.

Importantly, finance and funding are not neutral. The structure of finance is as important as the quantity of finance — both are key to the successful implementation of market-shaping and mission-oriented policy. The type of finance available can affect both where investments are made and the type of activity that is funded (Mazzucato, 2013). The forms of financial institutions and markets that exist have a material impact on activity in the real water economy. This makes it necessary to rethink the institutional financial ecosystem to foster a greater emphasis on the provision of long-term, patient finance and investment (Macfarlane and Mazzucato, 2018).

The cost and benefits of water-related investments raises important distributional issues. More than 50% of the projected financing requirements to achieve SDG 6 should be spent on the population with the bottom 40% of income (Hutton, 2022). Major challenges relate to fair cost allocation (who should pay? are those who created the pressures on water resources paying their “fair share” of the costs?) and affordability of financing instruments (how to assist those who cannot afford to pay for water supply and sanitation, or protect themselves against water risks?). Some water-re-

lated investments, especially concerning green infrastructure, frequently lack distinct revenue streams and assets that can be used as collateral (Baker, 2022). Further, grey infrastructure projects are long-lived, with a high initial investment and long payback period requiring long-term finance on affordable terms that may discourage a range of potential investors.

Distinct asset classes and types of water infrastructure have different capacities to access finance. Some have straightforward financing cases, i.e. when creditworthy borrowers have reliable revenues that can be secured and “ring-fenced”, and operational risks are well understood (e.g. reservoirs for hydropower generation, large wastewater treatment plants, or desalination plants for sea or brackish water). Others are less straightforward (e.g. green infrastructure for flood prevention, or decentralised water supply systems), but financing options are still available. Greenfield investment (e.g. the construction and start-up of a new desalination plant) raises different challenges and opportunities than financing the refurbishment of assets already in operation. The distinct risk-return profile and project attributes of each investment should, therefore, inform the appropriate financing strategy (Dominique and Money, 2022).

Barriers and pressures that need to be responded to in water financing include: (i) poorly targeted household subsidies, neglecting disadvantaged communities who are more exposed and vulnerable to water risks and bear the burden of the crisis; (ii) poorly designed agricultural subsidies leading to water pollution or shortages and wetland degradation; (iii) low tariffs for water supply and sanitation services that benefit users who can afford to pay more and deprive service providers of financial resources to connect those in need; (iv) a conservative bias towards large-scale grey infrastructures, with well-established financing models, translating into too much money going to projects that are capital-intensive and inflexible, thereby devaluing alternative options and increasing risks of maladaptation to an uncertain future; and (v), inequitable contributions from stakeholders compounding distributional issues such that those who pollute or put pressure on water resources do not, or only partially, pay for the cost of remediation.

Water finance is greatly mobilised by government such that there is an opportunity to ensure this finance is as strategically directed and as outcomes oriented as possible. The need is to design and implement effective water investment policies that target clear goals or missions with a view to ignite collective action and respond to the barriers that prevent beneficial change while accounting for the multiple water values. As the private sector tends to be risk-averse, bold mission-oriented funds that are willing to invest in the more uncertain part of the water innovation landscape (and areas with high capital intensity) can have a “crowding-in” role (Mazzucato, 2019). Further, it is important to consider how to share not only risks but also rewards. For example, governments can make public funding, whether directed using public procurement, grants, loans or other financial tools, conditional on activities and behaviours that maximise the common good and public value (Mazzucato, 2022).

Typically, financial markets fail to value water properly and fully incorporate water risks’ systemic nature into financial decisions (including avoidance of future liabilities). For instance, it has been estimated that the Dutch financial sector has in its equity portfolios a combined exposure of EUR 83 billion to facilities located in extremely water-stressed regions (Schellekens and Toor, 2019). Thus, direct financial flows can increase exposure and vulnerability to water risks and compound the depletion of freshwater resources.

A water action agenda on financing combines five pillars. Each pillar includes a suite of options: (i) make the best use of existing assets; (ii) ensure the full utilisation of available finance; (iii) strengthen the enabling environment to attract fit-for-purpose finance (e.g. climate finance, investments in nature-based solutions, revolving funds, microfinance, among others); (iv) harness new sources of finance, document how water affects the economy and fully consider how water risks materialise into financial risk; and (v) engage in the reform of development finance and global governance (OECD, 2022).



4.2.3 Recognising and reprioritising the “Three Infrastructures”

Key water goals associated with water infrastructure include enhancing water availability, improving water quality and reducing water-related risks (UNESCO, 2018). The traditional approach to achieving these goals has been to invest in, build and enlarge human-built (or grey) water infrastructure to store water inter-temporally, to divert water from within the landscape, to treat and distribute water, and to remove and treat wastewater. Almost all cumulative global water investments have been for grey infrastructure (e.g. dams, irrigation channels, pumping stations, treatment facilities, pipes, etc.).

The need to increase renewable energy generation and growing variability in inflows due to climate change (Douville et al., 2022) means that there are thousands of large multi-purpose or hydropower dams either under construction or planned (Zarfl et al., 2015; Grigg, 2019), many in the Global South. Human-constructed water storages can provide a range of important services (e.g. improve water availability, increase reliability of water flows and mitigate floods) (World Bank 2023). Nevertheless, while large dams provide a range of benefits, they also generate social and environmental costs (Zarfl et al., 2015), reallocate water among competing needs of water uses and water users, change landscapes, alter ecosystem services and affect the timing, magnitude and temperatures of water flows. Large dams also have dispossessed communities, as many as 80 million people by 2000 (WCD, 2000), without or with minimal compensation, and contributed to water injustice (Blake and Barney, 2021; Duflo and Pande, 2007).

While not diminishing the importance of grey infrastructure, especially in delivering WASH services, two other vital infrastructures must be highlighted. The first is “soft” infrastructure (e.g. regulation, policy and institutions), which provides the underlying rules about how water is used and supplied, and the costs recovered (OECD, 2015). The second is “green” or natural infrastructure (e.g. floodplains, wetlands, river channels, lakes and estuaries, soil, etc.) (Williams et al., 2022), which is part of existing ecosystem services. Stakeholders benefit from green and grey infrastructure in the form of private (e.g. pipe-delivered water to a house) and social (e.g. flood control) capital. All three (grey, green and soft) infrastructures are crucial to delivering improved water services and outcomes (Green et al., 2015).

Grey and green infrastructures can be complementary (see Table 4.1). For example, policies to avoid deforestation in upper catchments can support grey infrastructure actions, such as maintaining a dam for flood control. Green infrastructure may also substitute for grey infrastructure. For example, New York City has, for decades, conserved land in its catchments to maintain its ability to deliver a high-quality water source and to avoid additional and expensive water treatment facilities (Ashendorff et al., 1997).

Green infrastructure creates multiple benefits for biodiversity, climate change mitigation and adaptation, and disaster-risk reduction, and generates cultural, recreational and amenity values (Coates and Smith, 2012). It delivers a range of direct water services, such as groundwater recharge (Williams et al., 2022), and in urban environments may reduce storm runoff with constructed wetlands (Chung et al., 2021; OECD, 2015). The benefits of conserving green infrastructure can be enormous and reduce urban water suppliers' operating and capital costs by about half (McDonald et al., 2016). This benefit is because the more pristine the catchment, typically, the higher the water quality. In some cases, green and grey infrastructure cannot be or are prohibitively expensive to substitute. For example, conserving green infrastructure could be valued at as much as USD 3 trillion by 2050 in terms of avoided replacement costs for grey infrastructure (Arfanuzzaman et al., 2029; Vörösmarty et al., 2021).

TABLE 4.1 Grey and green infrastructure

Service	Grey infrastructure components	Examples of green infrastructure components and their function
Water supply and sanitation	Reservoirs, treatment plants, pipe network	Watersheds: Improve source water quality and thereby reduce treatment requirements Wetlands: Filter wastewater effluent and thereby reduce wastewater treatment requirements
Hydropower	Reservoirs and power plants	Watersheds: Reduce sediment inflows and extend life of reservoirs and power plants
Coastal flood protection	Embankments, groynes, sluice gates	Mangrove forests: Decrease wave energy and storm surges and thereby reduce embankment requirements
Urban flood management	Storm drains, pumps, outfalls	Urban flood retention areas: Store stormwater and thereby reduce drain and pump requirements
River flood management	Embankments, sluice gates, pump stations	River floodplains: Store flood waters and thereby reduce embankment requirements
Agriculture irrigation and drainage	Barrages/dams, irrigation and drainage canals	Agricultural soils: Increase soil water storage capacity and reduce irrigation requirements

SOURCE: Browder et al., 2019: 5

To be as effective as possible, soft infrastructure must be adapted to the capacities, regulations and processes in particular locations (Garrick, 2015; Grafton et al., 2019b). Multiple soft infrastructure frameworks have been developed (Rahaman and Varis, 2005; Pegram et al., 2013). The Water Governance Reform Framework has been applied to four different countries and includes the following considerations: (i) well-defined and publicly available reform objectives; (ii) transparency in decision-making and public access to available data; (iii) water valuation of uses and non-uses to assess trade-offs and winners and losers; (iv) compensation for the marginalised or mitigation for persons who are disadvantaged by reform; (v) reform oversight and “champions”; (vi) capacity to deliver; and (vii) resilient decision-making that is both beneficial and durable from a broad socio-economic perspective (Grafton et al., 2019b).

This framework, or any other approach to water reform, calls for resilience-based scenario planning or strategic investment planning for different investment pathways (Grafton et al., 2019a) that also consider barriers and underlying drivers (Brown et al., 2022). Scenarios help stress-test water-related and other investment decisions against their sensitivity for future developments, typically concerning the displacement of the water cycle and water limits. That is, resilience-based scenario planning assists with climate adaptation and can help to avoid the lock-in of sub-optimal infrastructure design or allocation of capital. Importantly, soft infrastructure requires adaptive processes because many of the world’s water crises are “wicked problems” (Grafton, 2017) that demand flexible actions to deliver the triple bottom line (Figure 4.4).



FIGURE 4.4 Actions for the Common Good, Three Infrastructures and Sustainable Pathways
SOURCE: The authors



4.3

Rethinking and renewing responses to water



4.3.1 Policy and regulatory frameworks

Economies require a bespoke regulatory framework to deliver the common good. A wide variety of non-economic regulatory, suasive and infrastructural instruments available to governments include: goals, targets and principles; water budget and water allocation plans; priority of use (which can be operationalised in a water allocation plan); human right to water and sanitation; recognition of the right of the river; conservation and sustainable of water-related ecosystems (e.g. recharge zones, wetlands and national parks); standards (e.g. ambient, discharge, water treatment, technology (forcing, limited), design, information, behavioural and management); assessments (Environment Impact, Strategic Environmental, Health Impact); suasive instruments (e.g. labelling and certification, public education); infrastructure (water supply systems, dams); property/riparian rights; and allocation of permits and contracts. Possible procedural instruments (right to information, public participation, access to civic space and access to courts) and dispute resolution (fact finding, third partner mediation and arbitration) include self-management and hybrid management; reporting, monitoring and enforcement are part of the suite of instruments available to govern water.

Many regulatory instruments cannot be replaced by economic instruments. Thus, in a new framework for the common good there must be an appropriate mix of economic and non-economic instruments. These instruments determine “who” has access to water and how it is accessed. The “who” must be comprehensive and recognise the self-determination, for example, of Indigenous People. At the (sub)national level, the instruments of water budgeting, a priority of use and permits are critically needed. Rules and instruments that determine which use (e.g. industry, agriculture, household) and which users (e.g. first use, individuals) of water are prioritised, and under what conditions, need to be re-examined through both a justice and sustainability lens with the goal to deliver the human right to water and sanitation for all (SDG 6).

At the global level, justice principles require adopting global norms of minimum access to water for WASH, agriculture, energy and infrastructure; minimum norms for quality standards applicable to different kinds of water bodies and to point and non-point pollution sources; and minimum norms of responsibility concerning the damage caused by extreme weather events. Transformational change to water reallocation, and how it is used, must offer practical and flexible options, share social responsibilities, and enable collective and just action that is bespoke to context, place, people and time.

BOX 4.2 Water accounting

Water accounting emerged in the 1990s and is part of the System of Environmental-Economic Accounting (SEEA) (Figure 4.5). As of 2022, 67 countries have produced water accounts.

Best practice water accounting includes a collaborative development process recognising the diversity of stakeholders and their values to ensure the relevance of the accounts; comprehensive coverage of water resources (surface, ground and soil water); industry and sectors (e.g. agriculture, mining, energy, water supply and sewerage industries plus households); development of multiple account types (stocks and flows, physical and monetary measurement units); regular, frequent and timely production; clear statements of data quality (including limitation); and a continuous improvement process.

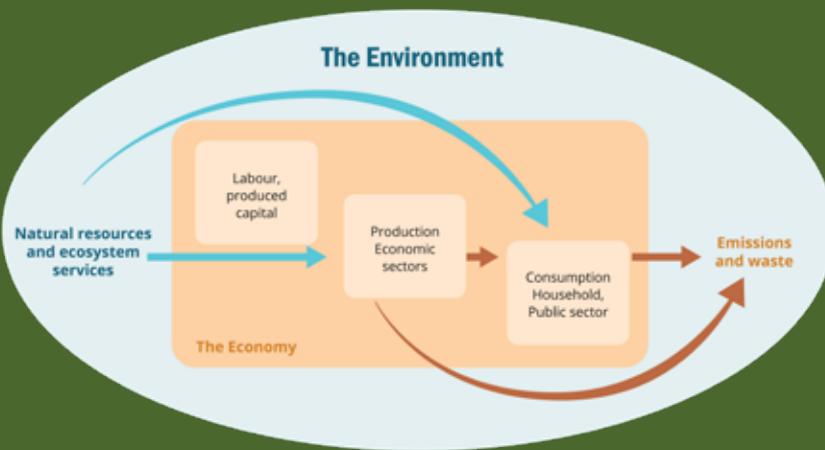


FIGURE 4.5 Environmental and Economic Context of System of Environmental-Economic Accounting
SOURCE: World Bank, 2021, Figure 2.1, p. 16



4.3.2 Water accounting and water budgets

Water budgets are a tool for quantifying the flows of water into and out of a well-defined hydrological system (Healy et al., 2007). They record all water stored and exchanged on the land surface (rivers, lakes), subsurface (aquifer, groundwater) and atmosphere (precipitation, evaporation). Such a “budget” measures the rate of change of water stored in an area that is balanced by the quantity and rate at which water flows into and out of a hydrological system. That is, the sum of stream inflows plus precipitation into a catchment per time-period equals the sum of evapotranspiration, stream outflows and the change in water storage in the catchment.

For water accounts to be effectively incorporated into decision-making about “who gets what, when and where”, they need to be provided in a timely manner for decision-makers (Bassi and Kumar, 2012; Vardon et al., 2023). While water accounts reveal what has happened, how water was used, by whom, and what were the economic and environmental outcomes, the information in water accounts must be interpreted and analysed by methods such as hydro-ecological-economic modelling (Grafton et al., 2022) and scenario forecasting (e.g. Pedro-Monzonís et al., 2016; Banerjee et al., 2019). Embedding water accounting into decision-making also requires a comprehensive multi-stakeholder process connecting civil society, the public and the private sectors. These processes can be supported by multi-stakeholder partnerships (Brouwer et al., 2016) that also create opportunities to improve data quality for water accounts. Thus, water accounting helps with shaping governance and economic decision-making while accounting for water stocks and flows.

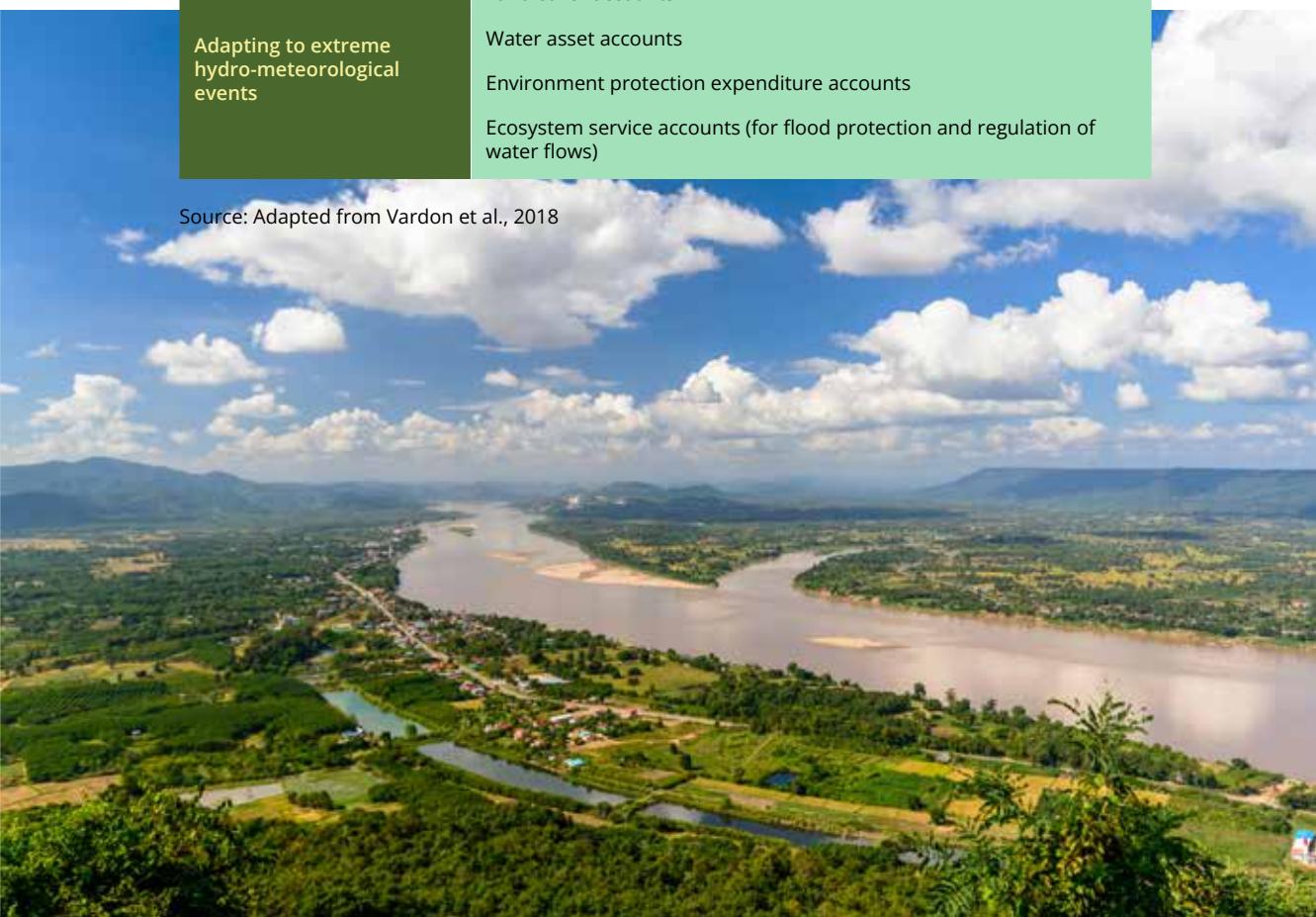
By consistently applying definitions, classifications and structures, water accounts can be linked to other environmental and ecosystem accounts and the System of National Accounts (SNA). This process allows multiple data sources to be assembled into a coherent and logical information system about stocks and flows of water. Water accounting is a process that supports the collection, analysis and interpretation of data in support of water governance and management and places water accounts into a macroeconomic context via the link to the SNA.

Water accounting's key strength is to provide a framework for integrating a wide range of water-related data with other information on the environment and economy. The challenge is that the data are not necessarily available to make water accounts as comprehensive as they need to be for decision-makers. For example, while water consumption is reported in many water accounts, some of the flows returning from the economy to the environment are not recorded due to insufficient data (Weckström et al., 2020). The key opportunities for water accounting are listed in Table 4.2.

TABLE 4.2. Water challenges and water accounts

Water Challenges	Water Accounts
Improving drinking water and sanitation services	Physical and monetary water supply and use tables SNA accounts (with an emphasis on the water supply and sewerage industries) Environment protection expenditure accounts Water asset accounts
Managing water supply and demand	Physical and monetary water supply and use tables Water asset accounts Land cover and land use accounts SNA accounts (with an emphasis on the water supply and sewerage industries)
Mitigating water resource degradation	Physical and monetary water supply and use tables (emphasis on return flows and operation on sewerage collection and treatment) Land cover and land use accounts Water quality accounts Environment protection expenditure accounts
Adapting to extreme hydro-meteorological events	Land cover accounts Water asset accounts Environment protection expenditure accounts Ecosystem service accounts (for flood protection and regulation of water flows)

Source: Adapted from Vardon et al., 2018





4.3.3 Understanding and responding to land-use changes

Changes in vegetation from land use and/or its interaction with climate change affect global and regional weather patterns. At the regional scale, changing land conditions affect the intensity, frequency and duration of extreme precipitation and associated hydrological events. Vegetation change affects the global water cycle through the green-water flux. For example, changes in forest or tree cover from afforestation, reforestation and deforestation directly affect local and regional surface temperature and groundwater through water and energy exchanges. The green-water flux from large tracts of forests such as the Amazon or the Western Ghats, India, can contribute to rain in downwind regions, sometimes distant from the source (Spracklen et al., 2012) (Box 4.3).

The excess availability of blue water via flooding or green water via evapotranspiration at the cost of scarce blue water is problematic from the local to the global. A more desirable mix of green and blue water is needed across regions (Krishnaswamy et al., 2009). For instance, forests can create different trade-offs between gains to blue water and contributions to green-water flux at local or regional scales (Krishnaswamy et al., 2018). Tree-plantations for climate mitigation or other purposes can affect the quantity and quality of groundwater. Attention must, therefore, be paid to afforestation tree-densities for carbon sequestration to ensure the safe use and consumption of green-water and blue water fluxes, noting that green water consumption from deep-rooted tree plantations can deplete groundwater and induce trade-offs with other agricultural water uses (Clark et al., 2021; Ilstedt et al., 2016). Further, green water consumption is associated with the “topping off” of crops by blue water irrigation, such as for millets in semi-arid and sub-humid regions (Saxena et al., 2018), and with forests that export rain to dry regions downwind (Paul et al., 2018).

Irrigation is a key source of land-use and land-cover-induced impact on green water flux. Irrigation green water impacts are substantial and may have increased global vapour flows or green-water flux by about 2,600 km³ per year (Gordon et al., 2005). Irrigation affects precipitation regionally or downwind due to changes in surface energy and moisture budgets (Gordon et al., 2005).

Freshwater ecosystems or freshwater wetlands, their biodiversity and ecosystem services, are one of the most threatened biomes globally (Bassi et al., 2014; IPBES, 2022; WWF, 2022), with inland waters and freshwater ecosystems having some of the highest rates of decline. Some 35% of the global area in wetlands is estimated to have been lost since 1970 (Ramsar Convention on Wetlands, 2018).

The absence of a specific and exclusive SDG for fresh-water ecosystems, unlike those for terrestrial ecosystems (SDG 15 Life on Land) and marine ecosystems (SDG 14 Life under Water), is a deficiency in the 2030 Development Agenda (IPCC, 2019a). This is despite SDG Target 15.1 including the conservation, restoration and sustainable use of inland freshwater ecosystems and their services, including specifically wetlands, and SDG Target 6.6 including protecting and restoring water-related ecosystems, including wetlands, rivers, aquifers and lakes. This poses a challenge in managing trade-offs from water withdrawals from rivers and wetlands for supplying drinking water (SDG 6), large and small hydro projects for irrigation (SDG 2) and hydropower (SDG 7). Water with-

drawal and consumption contribute to the ecological fragmentation of rivers (Jumani et al., 2020; IPCC, 2019a; Richter and Thomas, 2007), while invasive species in wetland ecosystems diminish biodiversity, ecosystem services and water security (IPBES, 2022; Catford, 2017).

The Conference of the Parties (COP) 15 of the Convention on Biological Diversity in 2022 defined a goal and targets for effective conservation and management of at least 30% of the world's lands and inland waters by 2030; emphasising conservation of areas of biodiversity importance and ecosystem functioning while respecting the rights of communities. By comparison, only 17% of the world's terrestrial areas are currently under direct protection, noting that the area of protected inland waters is uncertain. Achieving the COP15 30% conservation goals will require both land sharing and land sparing within climate adaptation measures that maintain biodiversity conservation and key ecosystem services to deliver water, food and climate security (Srivathsan et al., 2023).

BOX 4.3 What are the consequences of planting one trillion (additional) trees?

Globally, there are an estimated 3.04 trillion trees (Crowther et al., 2015) that occupy a global land surface area of about 40 million km² (FAO, 2020). This current globally forested area is about the combined land surface area of North America, Central America and South America.

As a response to anthropogenic climate change and biodiversity loss, and to help deliver the global target of "Net Zero by 2050", there is a global initiative (see 1t.org) to plant one trillion additional trees. The key justification for this initiative is that:

Growing, restoring and conserving 1 trillion trees over the coming decade could result in up to 12 Gt CO₂ being sequestered from the atmosphere each year, with the same trees storing up to 205 Gt of CO₂-equivalent once mature. (World Economic Forum, 21 January 2020)

To what extent additional carbon sequestration from planting trees occurs depends on what the previous land use was, that is, the net change in carbon stocks following conversion to forest from current land use. This carbon sequestration "additionality" depends, in part on, the resilience of forests as carbon sinks (Dass et al., 2018) versus alternatives (e.g. grasslands), especially to impacts of extreme heatwaves, droughts and wildfires. It further depends on where (e.g. soils, topography, climate zone) the trees are planted, the species type and the ongoing conservation of the additional trees to prevent or mitigate logging, wildfires, disease, and heat and water stress.

Afforestation can both increase and decrease blue freshwater availability (e.g. rivers, lakes, aquifers) depending on what additional trees are planted, where they are planted, their canopy cover and tree density, and the age and the species of trees (Jones et al., 2022). The land-use change needed to grow an additional one trillion trees cannot lead to a reduction in croplands, otherwise there would be insufficient land in food production to feed more than 8 billion people in 2023 and into the future (Gerten et al., 2011; Rosa et al., 2021). Nor can this change reduce key ecosystems provisioning services.

To plant an additional one trillion trees, not currently in forest, based on the current global average tree density (tree density, typically, varies by forest type from 200 trees per hectare to over 1,000 trees per hectare and globally averages 760 trees per hectare), would require an additional surface area of about 13 million km². This area equals about 12% of the world's habitable terrestrial surface area, larger than the global area devoted to crops, or about 11 million km² (Ritchie, 2019), and will make up an area larger than the surface area of China, the United States or Canada. The only terrestrial biome of sufficient size globally to potentially meet the land surface area requirements for an additional one trillion trees is grasslands, located almost entirely in sub-tropical and tropical zones. The implications of such a huge land use change on the water cycle and food availability, and who benefits and who bears the costs, needs full consideration. Above all, it requires systems thinking that connects the dots between water, energy and food to planetary boundaries and limits.

4.3.4 Trade rules

Trade facilitates the development of goods, services and technologies, such as drought resistant crops, water conservation and storage systems, water pollution management technologies and products (WTO, 2022). These goods and technologies related to water management have been identified by countries in the Global South as one of the needs and priorities for technology transfer (Martínez-Zarzoso and Chelala, 2021).

Trade can mitigate water scarcity. Virtual water trade is in the order of 300 km³ per year (Scanlon et al., 2023), with the largest virtual exports coming from the United States, India and Pakistan (see Figure 4.6). Virtual water trade embedded in the production of food, improves global food security by allowing water-constrained countries to import water-intensive agricultural products rather than producing them domestically. Nevertheless, trade in virtual water can enhance water inequalities and damage the environment of water-intensive exporting countries if the external costs of water consumption are not fully considered. Consequently, sustainable national water policies are needed if international food-water trade is to be consistent with the water cycle as a global common good.

Food export restriction is a key food-water trade concern given that ad hoc food export-supply constraints increase in anticipation or during a food price spike. These price spikes are closely linked to water-related shocks like floods and droughts. For instance, the severe food price shocks of 2008–10 and 2020–22 were, in part, caused by food supply shocks that arose from reduced water availability (Katic and Grafton, 2023). Thus, connecting water-food-energy to food trade within borders and across frontiers is important if global trade is to contribute to the global common good.

Agriculture subsidies are another set of policy tools that influence water use trade-related water policy tools. Under current global trade rules, subsidies for the construction of water supply facilities, and dams and drainage schemes are allowed without limitation, provided certain conditions

are met (OECD, 2022). These conditions require that expenditures are directed to the provision or construction of capital works only and must exclude the subsidised provision of on-farm facilities other than for the reticulation of generally available public utilities. Under these rules, subsidies for agricultural inputs, operating costs or preferential water user charges are subject to trade limitations. Nevertheless, low-income countries may provide input subsidies targeted at low-income and resource poor producers.

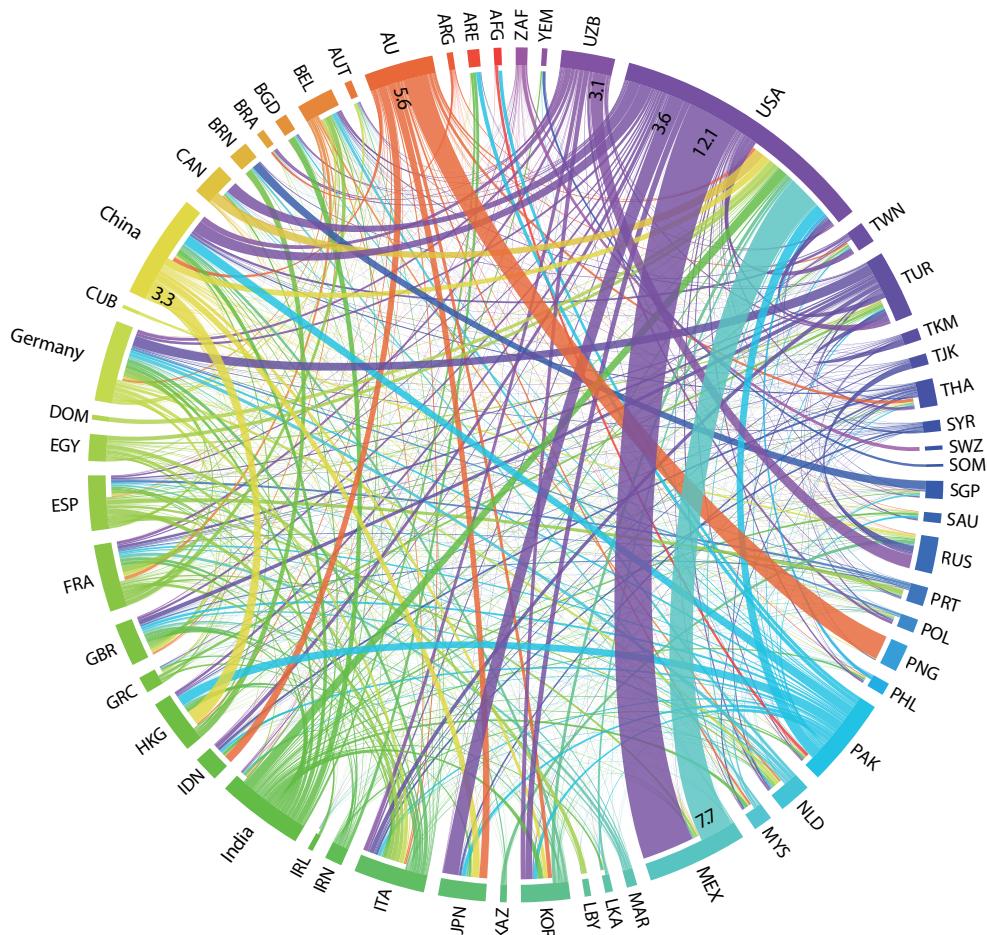


FIGURE 4.6 Blue water virtual flows between countries (1996–2005)

SOURCE: Scanlon et al., 2023

A photograph showing a person's hands being washed under a small, reddish-orange outdoor faucet. The person is wearing an orange long-sleeved shirt with white stripes on the cuffs. A watch is visible on their left wrist. The background is a textured, light-colored wall.

05

Water for the Global Common Good

The safe and just delivery of human well-being and ecosystem health by 2050 is fundamental to the future of everyone. Its accomplishment must be within global water limits, recognise that the water cycle is a Global Common Good and deliver transformational change, from the local to the global.

Humans face a global challenge of an altered water cycle caused by climate and environmental change combined with the local changes of misuse and overdraft.

Responding to this crisis is about framing collective choices and common goals, principles, targets and indicators; identifying system transitions and response options that underpin and accelerate implementation from the local to the global; and creating key enabling conditions and instruments to catalyse change, including governance, finance, institutional capacity, technology and innovation, citizen mobilisation and partnerships. For example, in the case of finance, a common good mission would expand its mandate beyond investment volumes and risk-return relationships to the sources and type of finance and to what ends it is directed, the design of institutions (i.e. what the institutions do and their effectiveness in implementation) and the concrete characteristics of the relationship between public and private actors (i.e. the dialogues between actors and the practices of deliberative democracy). This requires local to global actions based on a new framework on the economics of water and includes market shaping (e.g. regulatory mechanism, incentives) and state shaping (legal, regulatory and rights frameworks, subsidiarity, balancing state, private and community-driven processes), within which water connects the economy, all of society and nature.

5.1 Next steps

The GCEW considers the Water Cycle as a Global Common Good, as both an organising principle and a driver of transformational change (e.g. simultaneously implementing sustainable development, climate action, biodiversity conservation and disaster risk reduction) from the local to the global. Building on its own research and synthesis, including this report for the UN 2023 Water Conference, calls for evidence, and Societal Dialogues, the GCEW will in 2023–24 assess a range of Response Options to the water crisis. This process will connect to and be informed by synergies and trade-offs with the SDGs, climate adaptation and mitigation, and biodiversity conservation. The resulting actions must be appropriate to context and history. They must also be co-created via meaningful engagement with national and local governments, industry, civil society, science and knowledge institutions, farmer organisations and unions, youth, and Indigenous and local communities.

Given many historically entrenched barriers, transformational change must offer practical ways forward that promote shared and social responsibilities, and collective action that promotes justice and equity, sustainability and resilience. This change must add value to the existing global institutional architecture, share water equitably and consider all the values of water.

The elements of a new framework on the economics of water include: systems thinking especially around the Water-Energy-Food-Environment Nexus; supporting collective action and governance to deliver goal and mission-orientated outcomes; increasing, innovating and scaling up finance for water; braiding water knowledge and values; water accounting and water budgets; valuing and pricing water for equity, efficiency and sustainability; designing effective and equitable water markets; recognising and reprioritising action around three core water infrastructures (grey, green and soft); understanding and responding to ecosystem degradation and promoting nature-based solutions; and supporting sustainable food-water trade.

An Agenda for Water Action must be: (i) at multiple geographical scales across the Global South and North; (ii) within the broader context of effective multilateralism; and (iii) based on the latest science and political engagement and supported by Societal Dialogues across a diversity of peoples at global, regional, national and local scales. Without broad-based support for local to global transformative actions, we will not achieve a safe and just water future.

5.2

Transformational goals

This section outlines ten transformation goals that, if operationalised from the local to the global scale, would effectively respond to the water crisis. These goals are centred on the water cycle as a global common good and water as an organising principle. How these goals might be operationalised, and at what scale, will be tested by the GCEW over 2023–24, via detailed assessments of scientific evidence, review of cases of implementation, and with a series of global and regional societal dialogues to inform the final report of the Global Commission for the UN Summit for the Future in 2024.

The safe and just delivery of human well-being and ecosystem health by 2050 is fundamental to the future of everyone. Its accomplishment must be within global water limits, recognise that the water cycle is a Global Common Good and deliver transformational change, from the local to the global.

The GCEW's transformational and multi-dimensional goal can only be achieved through collective action involving a new social contract between citizens, governments, businesses, Indigenous Peoples and civil society delivered by the simultaneous implementation of 10 strategic local to global goals.

Three clusters of these goals enable a set of system transitions to accelerate implementation across the 2030 Development Agenda, climate action and biodiversity conservation for: (A) **transforming economic and social systems** (food, health, sustainable cities and resilient infrastructure, and sustainable livelihoods), (B) **supporting natural systems** (sustainable land use and ecosystem, and biodiversity conservation) and (C) **establishing cross-cutting integrative missions** (enhanced financing and institutional capacity; innovation and technology transfer; and limiting unsustainable virtual water trade). For example, the reallocation and improved management of blue and green water can shift development pathways to deliver clean water and sanitation (SDG6) to enable Good Health and Well Being (SDG3) and Gender Equality (SDG5), protect water-related terrestrial ecosystems (SDG15) and through water innovation and practices that improve food security and accelerate the transition to Zero Hunger (SDG2) and No Poverty (SDG1).

These 10 time-bound outcome-oriented goals will need to be negotiated, designed, financed and implemented by strengthened institutions at the local, national and global level. These goals respond to the root-causes of the interrelated global systemic crises with water as a key driver: economic stability, conflict, inequality, climate and biodiversity. A set of water and SDG-linked potential goals and indicative means of implementation are presented below.

A

Transforming Economic and Social Systems

1 Food systems transition: Secure food systems are vital and increasingly at risk due to climatic uncertainty and anthropogenic land-use changes. Food and fibre production consumes by far the most water of any human activity globally and is a major polluter of drinking water. There is a need to balance growing food production with maintaining healthy systems for future generations.

Potential goal: Sufficient, safe, resilient and sustainable all-year round nutrition for all by 2050 [linked to SDGs 1, 2, 6, 13 and 15].

Indicative means of implementation: Timely access to adequate, affordable and sufficient water services that account for local and global water consumption limits, water and precipitation extremes, local water-related land ownership regimes, and water for ecological flows and biodiversity conservation and cultural values; secure and equitable access to land and linked green and blue water; water consumption limits that incentivise increased agricultural productivity, production and improved nutrition access; climate smart agriculture; diversified livelihoods; improved farmer and worker income security with lowered debt; appropriate dietary and behavioural shifts; pro-social demand-side measures and incentives; improvement in soil health, genetically diverse seed stock; equitable and just access to affordable finance; efficient and equitable prices and transfers; and a resilient (water-energy-food-land-trade) policy regime and food system resilience to drought, flooding and climate-related extreme events.

2 Health systems transition: Lack of access to safe water and sanitation and hygiene is linked to multiple health risks ranging from diarrhoea and cholera to cancer and death. Limiting solutions to “pipes, taps and toilets” constrains the diversified and decentralised possibilities ranging from rainwater harvesting and conservation to localised sanitation and waste disposal solutions that can serve everyone (including nature).

Potential Goal: Universal access to safe drinking water, sanitation and hygiene to deliver good health and well-being for all, by 2050 [linked to SDGs 3, 5 and 6].

Indicative means of implementation: Universal access to safe and affordable drinking water, sanitation and environmental health services; restoring impacted water-related ecosystems to end water-borne and WASH-related diseases from unsafe water and sanitation, lack of hygiene and pollution; and limiting water-related pollution impacts.

3

Sustainable cities and resilient infrastructure systems transition: Poor design and implementation, inadequate regulation, and lax enforcement result in inefficient water allocation, finance and inequitable access to services, or exposure and vulnerability to water risks. Deficient institutional structures (corruption and rent seeking) also discourage (private) finance and increases pressure on public funding. Inadequate planning and investment in adapting to climate change and disaster preparedness.

Potential goal: Safe, inclusive, climate and disaster resilient and sustainable cities, settlements and infrastructure for all, by 2050 [linked to SDGs 6, 9, 11, 13].

Indicative means of implementation: Universal access to safe and affordable drinking water, sanitation and hygiene services and adequate services of quality water for industrial use, local and regional food systems, ecological flows and biodiversity conservation drawn from resilient low-carbon grey, green and blue water infrastructure; water security and reliability through efficient and equitable pricing complemented by recycling and reuse of blue, grey and black water; limiting pollution of surface and groundwater; access to sustainable green public spaces; water-sensitive urban, peri-urban and rural economic linkages and sustainable regional and transboundary water services; appropriate institutional and financing arrangements and technological choices; and urban resilience to drought, flooding and climate-related extreme events.

4

Sustainable livelihoods systems transition: Safe and secure employment and opportunities to build human and social capital is critical to the well-being of individuals, communities and economies. In the absence of collective action, much of the growth in employment in economies may fail to deliver meaningful employment and a “living wage”.

Potential goal: A water-secure and resilient agricultural, industrial and services economy with full and productive employment and decent jobs for all, by 2050 [linked to SDGs 2, 8, 9, 11 and 12].

Indicative means of implementation: “Decent job” creation in green, water and labour intensive and high value-added that also offers employment opportunities for youth and the economically disadvantaged.

B Supporting Natural Systems

5 Sustainable land use and ecosystems transition: Multiple global crises (climate change, biodiversity loss, excess water consumption) are compromising the future of humans and the natural environment. Responses require a reshaping of states and markets to ensure the costs of action do not prevent the transition from business-as-usual to sustainable pathways.

Potential goal: Return to a safe global operating space for green and blue water by 2050, via sustainable land use and cover and resilient terrestrial ecosystems worldwide [linked to SDGs 6, 13 and 15, the Paris Climate agreement and Global Biodiversity Framework].

Indicative means of implementation: Support green infrastructure and maintain adequate water for ecological flows and biodiversity conservation; conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, including wetlands; prioritising green infrastructures to enable access to safe water rather than only relying primarily on grey infrastructural solutions; remediation of damaged catchments and depleted aquifers; reduction and halting of deforestation, restoration of degraded forests and the sustainable management of forests; actions to combat desertification and the restoration of degraded land and soil; and responding to trade-offs and conflicts with land cover-related carbon capture and storage.

6 Biodiversity conservation transition: The world is experiencing a mass extinction event. Actions need to place humans within, rather than separate to, nature and to connect the dots between human activities and environmental outcomes.

Potential goal: Biodiverse and resilient freshwater ecosystems worldwide, by 2050 [linked to SDGs 6 and 15, the Paris Climate agreement and Global Biodiversity Framework].

Indicative means of implementation: Balancing adequate water flows for human purposes with ecological flows and biodiversity conservation, including wetlands; improved sewerage systems to substantially reduce waste flowing into water systems; reduction in the degradation of natural habitats; halt in the loss of biodiversity; diminished impact of invasive species on land and water ecosystems; and insertion of ecosystem and biodiversity values for growth into development processes, national and local planning, and the national accounts.

7**Water quality transition:** Surface water quality is declining in many parts of the world.

This is adding to a health, environmental and social burden on humans and degrading natural environments that generate important ecosystem services.

Potential goal: Improving water quality across the water cycle to adequate standards for human and ecological health and economic end-uses [linked to SDGs 6, 12 and 15].

Indicative means of implementation: Conservation and management of water, especially sources; effective treatment, recycling and reuse of blue, grey and black water; limiting pollution of surface and groundwater; protecting and restoring impacted water-related ecosystems; incentives for reducing pollution; strong regulation and monitoring processes to prevent pollution; appropriate agricultural, horticultural, industrial and urban development policies; and deployment of appropriate technologies.

C**Establishing Cross-cutting Integrative Missions**

A set of integrative pathways to deepen and accelerate the implementation of these seven goals from the local to the global, to deliver on efficiency, equity, justice and sustainability and the promise of not leaving any person, any place or any ecosystem behind.

8

Enhanced financing and institutional capacity: Huge financing gaps exist for grey and green infrastructure over the coming decades without which the SDGs will never be achieved.

Potential goal: Establishing financial structures and partnerships and building capacities to deliver water-related missions and sustainable practices that deepen economic and financial sector resilience to water-related shocks and crises and ensure a high rate of social, not just financial, rate of return [linked to SDGs 2, 6, 10, 16 and 17].

Indicative means of implementation: Building a widely accessible planetary information system and linked governance frame connecting multiple sources of water across the water cycle with diverse economic end-uses embedded in the water system transitions; dramatically enhancing water-related infrastructure (grey and green) investment by redirection, altering investment horizons and discount rates, and engaging with the multiple monetary and non-monetary values of water; establishing a high-level scientific, economic and governance global panel and open knowledge platform on water; strengthening institutional capacities for water governance, financing and implementation and the skills and abilities of workers, experts and decision-makers to support frontlines workers in implementation; and establishing global early warning systems, exposure and vulnerability reduction measures and, where appropriate, hazard modification or planned retreat in the face of systemic water shocks.

9

Innovation and technology transition: Innovation must go beyond income and wealth creation to include responses to planetary limits and support a water transition analogous to the energy transition. Technologies developed in one context and place do not necessarily achieve the intended outcomes and may result in unintended consequences. Thus, technologies need to be climate adapted and encouraged to mitigate or resolve local problems including delivering on the goals of communities.

Potential goal: Acceleration of social, institutional and technical innovation, sustainable water consumption practices, and localised decentralised solution options across the water cycle, especially in water-stressed regions, by 2030 [linked to SDGs 8, 9, 10, 11, 13 and 17].

Indicative means of implementation: Appropriate water and other sectoral industrial and innovation policy; building on successful local and Indigenous values and practices and deploying them across scale and transition; increased investment and incentives for development and deployment; braiding different knowledge streams; and strengthening institutional capacities and knowledge systems to build a diverse culture of innovation.

10

Limiting unsustainable virtual water trade: Some water-stressed regions are major producers and exporters of food and resources to regions that are water rich. Responding to this contradiction is vital as climatic uncertainty is increasing water shortages in arid and semi-arid locations and will undermine global food resilience.

Potential goal: Ensure the virtual water trade does not compromise our water future and supports a just, equitable and sustainable level by 2050 [linked to SDGs 1, 2, 13, 15 and 17].

Indicative means of implementation: Removing inefficient and wasteful water subsidies and tariff/non-traffic barriers that contribute to an unsustainable virtual water trade; enhance water and linked carbon disclosure in trade systems; develop just and equitable trade policies that do not worsen water scarcity in water-stressed regions; and operationalise the water-energy-food nexus to promote resilient and sustainable systems.

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Annex

The Global Commission on the Economics of Water

The Global Commission on the Economics of Water (GCEW) was established in May 2022 at the initiative of the Government of the Netherlands as co-host of the UN 2023 Water Conference, with the aim of re-envisioning the economics and governance of water, and completing the sustainability trilogy that began with the Stern Review on the Economics of Climate Change and the Dasgupta Review on the Economics of Biodiversity. It is co-chaired by Mariana Mazzucato, Ngozi Okonjo-Iewala, Johan Rockström and Tharman Shanmugaratnam, and comprises an independent and diverse group of experts from the fields of science, economics and policy-making, and with leadership experience at community, city, national and multilateral levels. Its work has been ably facilitated by a secretariat at the OECD. The GCEW's views and recommendations are however independent of either the Government of the Netherlands or the OECD.

Members of the Commision

CO-CHAIRS	Mariana Mazzucato Professor at University College London & Founding Director of the UCL Institute for Innovation and Public Purpose	Ngozi Okonjo-Iewala Director-General, World Trade Organization
	Johan Rockström Director, Potsdam Institute for Climate Impact Research	Tharman Shanmugaratnam Senior Minister, Singapore
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Yvonne Aki-Sawyerr Mayor of the City of Freetown, Sierra Leone	Alicia Bárcena Ibarra Former Executive Secretary of CEPAL, Chile
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GLOBAL COMMISSION on the
ECONOMICS OF WATER



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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