

The United Nations World Water Development Report 2020

WATER AND CLIMATE CHANGE

Facts and Figures



Global water use has increased by a factor of six over the past 100 years (Figure 1) and continues to grow steadily at a rate of about 1% per year (AQUASTAT, n.d.)¹ with increasing population, economic development and shifting consumption patterns. One study concluded that the world could face a 40% global water deficit by 2030 under a business-as-usual scenario (2030 WRG, 2009).

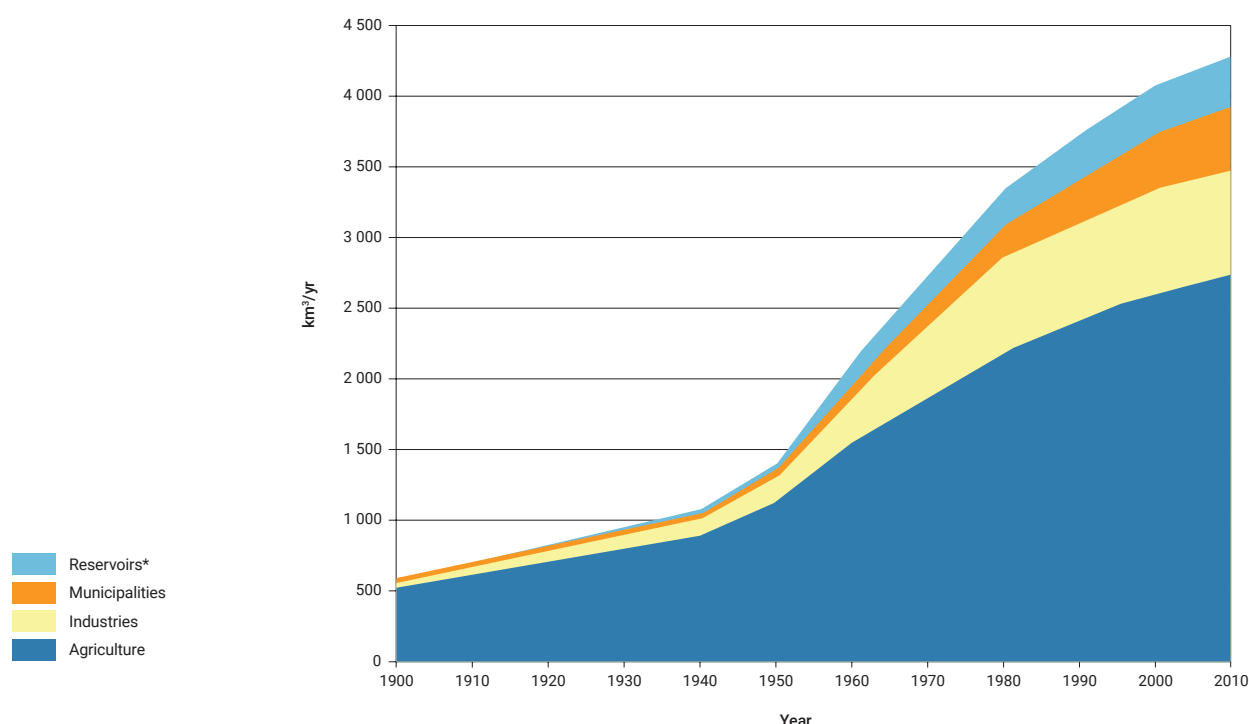
Globally, the rate of groundwater depletion has doubled between 1960 and 2000, equalling 280 km³ per year in 2000 (PBL Netherlands Environmental Assessment Agency, 2014). Without good management strategies, this will entail huge risks to life (OECD, 2012).

According to the World Economic Forum, since 2014 extreme weather events have been the first or second global risk in terms of likelihood, and water crises have been in the top five in terms of impact (WEF, 2019).

The rate of greenhouse gas (GHG) emissions is at an all-time high (WMO, 2019). Even if emissions are brought in line with current political pledges on the nationally determined contributions (NDCs) under the Paris Agreement, the scientific community is highly confident that the global average temperature will surpass pre-industrial levels by at least 1.5°C after 2030 (IPCC, 2018a).

Projections of the needs for water security investment diverge, but they all indicate that the scale of investment ought to increase significantly. Global estimates range from US\$6.7 trillion by 2030 to US\$22.6 trillion by 2050 (WWC/OECD, 2015).

Figure 1 Global water withdrawals throughout the previous century



Note: *Evaporation from artificial lakes.

Source: AQUASTAT (2010).

¹ For all sources cited in this document, please refer to the full report available at www.unesco.org/water/wwap.

Climate change

Since the mid-20th century, changes in the intensity and frequency of extreme weather and climate events have been observed, including a decrease in cold temperature extremes, an increase in warm temperature extremes, an increase in extremely high sea levels and an increase in the number of heavy precipitation events in a number of regions (Min et al., 2011).

Climate projections indicate with high confidence that extreme precipitation events will become more intense and frequent in many regions, but also that heatwaves will occur more often and last longer. The former will increase global flood risk (Hirabayashi et al., 2013), while the latter is expected to make droughts more intense (Trenberth et al., 2014). These risks are unevenly distributed geographically, and are generally larger for vulnerable people and communities in countries at all levels of development (IPCC, 2014a).

Water availability and stress

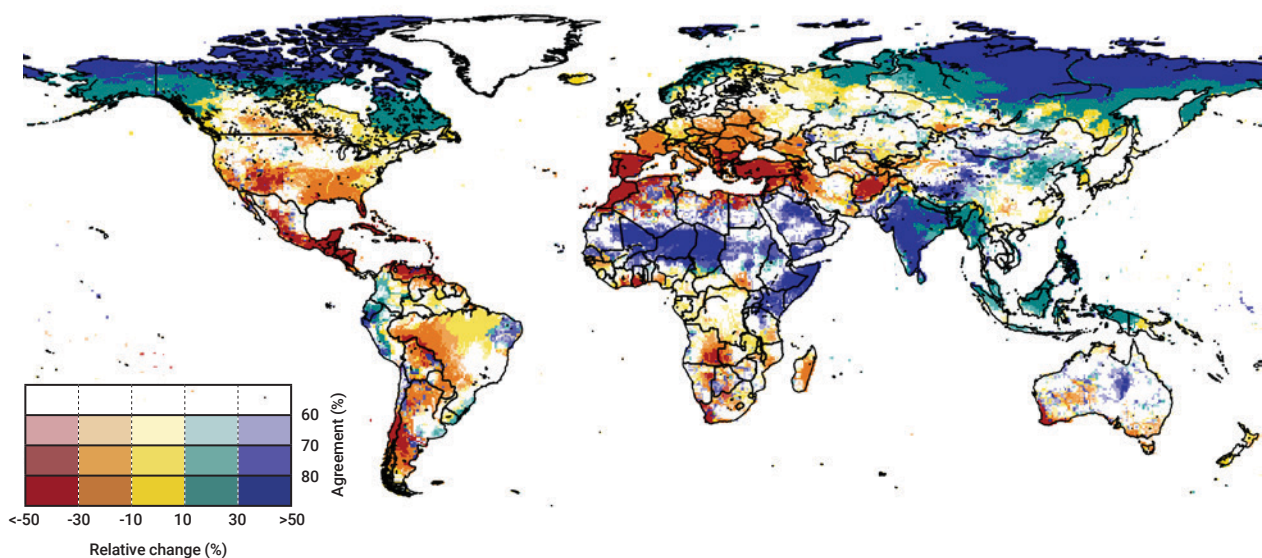
Since water mediates much of the climate change impacts on agriculture, increased water scarcity in many regions of the world presents a major challenge for climate adaptation.

Changes in precipitation and temperature (Figure 2) will directly affect the terrestrial water budget (Schewe et al., 2014). Evaporation from the land surface is expected to increase as a result of the global trend of rising air temperatures in all but the driest regions, where the lack of water prevents such an increase. This increase may be offset by an increase in precipitation, but in many regions and especially in those areas where rainfall volumes will decrease, this leads to decreasing streamflow volumes and a decrease of water availability in different seasons (IPCC, 2018a).

Such decreases will affect water availability directly, for water withdrawal for agriculture, industry and domestic supplies, as well as for in-stream uses such as power generation, navigation, fisheries, recreation and, last but not least, the environment.

Climate change-induced changes in the cryosphere are also widespread, leading to a global reduction in snow and ice cover (Huss et al., 2017). Snow cover, glaciers and permafrost are projected with high confidence to continue declining in almost all regions throughout the 21st century (IPCC, 2019a).

Figure 2 Climate change scenario trends in water availability



Note: This figure depicts the relative change in annual discharge at 2°C temperature increase compared with present day, under RCP8.5.

Source: Schewe et al. (2014, fig. 1, p. 3246). The Attribution Share-Alike 3.0 IGO (CC BY-SA 3.0 IGO) licence does not apply to this figure.

Accelerated melting of glaciers is expected to have a negative effect on the water resources of mountain regions and their adjacent lowlands, with tropical mountain regions being among the most vulnerable (Buytaert et al., 2017). Although the accelerated melting of glaciers may locally and temporarily increase streamflow, the reduction of glacier cover tends to lead to more variable river flows and reductions in baseflow in the long term, as well as changes in the seasonal timing of peak streamflow.

Water use has been growing at more than twice the rate of population increase in the last century (FAO, 2013a). Combined with a more erratic and uncertain supply, this will aggravate the situation of currently water-stressed regions, and generate water stress in regions with currently abundant water resources.

Water stress already affects every continent (Figure 3). Physical water scarcity is often a seasonal phenomenon, rather than a chronic one (Figure 4), and climate change is likely to cause shifts in seasonal water availability throughout the year in several places (IPCC, 2014a).

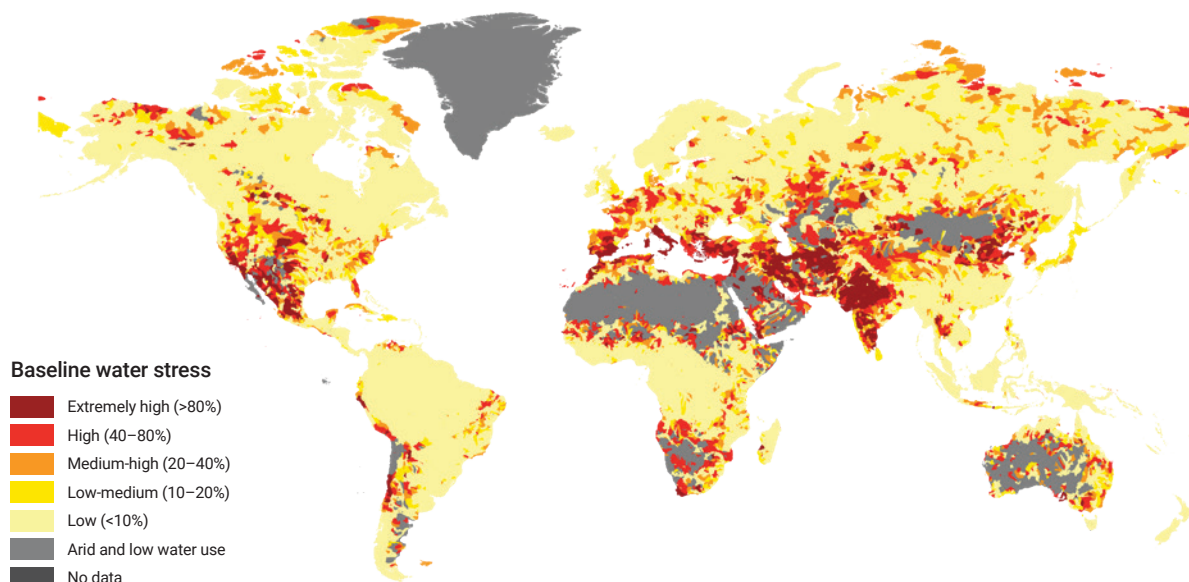
About four billion people live under conditions of severe physical water scarcity for at least one month per year (Mekonnen and Hoekstra, 2016). Around 1.6 billion people, or almost a quarter of the world's population, face economic water shortage, which means they lack the necessary infrastructure to access water (UN-Water, 2014).

Studies predict that water scarcity will continue to increase in the future, with around 52% of the world's population living in water-stressed regions by 2050 (Köbel et al., 2018).

Ecosystem degradation and water quality

Wetlands,² including peatlands, accommodate the largest carbon stocks among terrestrial ecosystems and store twice as much carbon as forests (Crump, 2017; Moomaw et al., 2018). However, degraded wetlands are significant sources of GHGs. Warmer climates could lower the rate at which peatlands accumulate carbon over the long term (Gallego-Sala et al., 2018). Burnt and drained peatlands account for nearly 5% of the global CO₂ emissions caused by humans (Crump, 2017).

Figure 3 Annual baseline water stress



Note: Baseline water stress measures the ratio of total water withdrawals to available renewable water supplies. Water withdrawals include domestic, industrial, irrigation and livestock consumptive and non-consumptive uses. Available renewable water supplies include surface and groundwater supplies and considers the impact of upstream consumptive water users and large dams on downstream water availability. Higher values indicate more competition among users.

Source: WRI (2019). Attribution 4.0 International (CC BY 4.0).

² A wetland is a distinct ecosystem that is inundated by water, either permanently or seasonally, where oxygen-free processes prevail. The main wetland types are swamp, marsh and peatland (bog and fen), and also include mangroves and seagrass meadows (Keddy, 2010).

Restoration and conservation of wetlands is an important mitigation measure. Griscom et al. (2017) suggest that around a third of the GHG mitigation until 2030 can be attained through ecosystem-based mitigation, to which wetlands can contribute a share of 14%. Taking into account that wetlands offer multiple co-benefits – including flood and drought mitigation, water purification, and biodiversity – conservation of wetlands is an important mitigating measure.

Over the past 100 years, the world is estimated to have lost half its natural wetlands and with this a significant number of freshwater species (UN Environment/UN-Water, 2018). The loss rate of wetlands is three times higher than that of forests (Ramsar Convention on Wetlands, 2018).

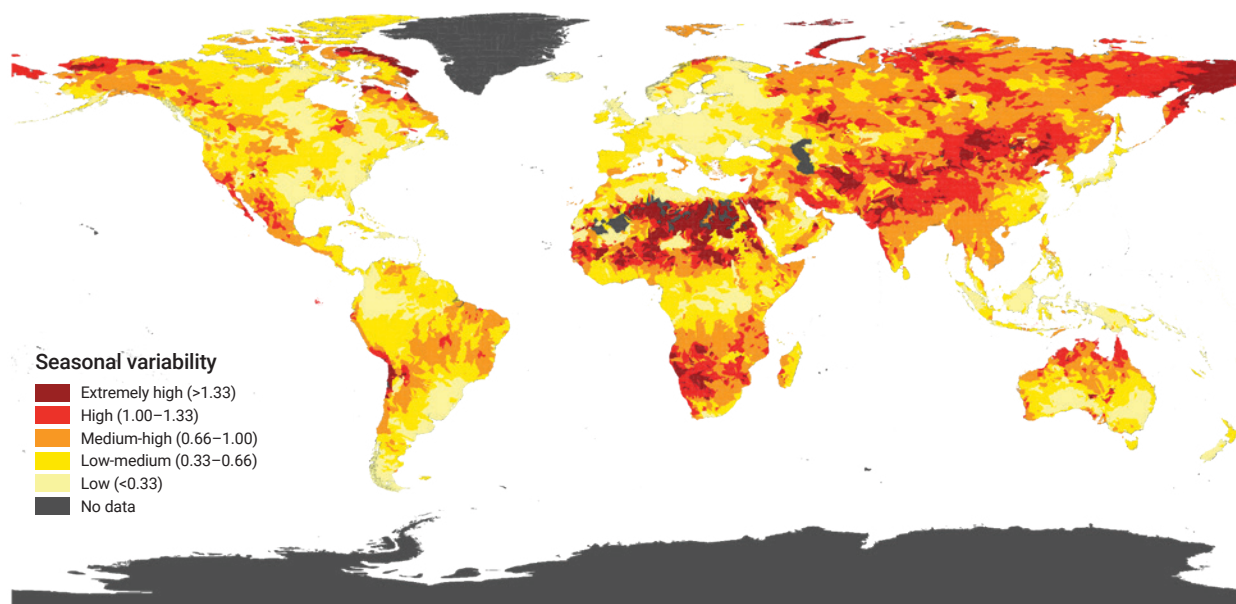
Water depletion and pollution are the major causes of biodiversity loss and ecosystem degradation, which, in turn, reduce ecosystem resilience, making societies more vulnerable to climate and non-climate risks.

Climate-induced harmful algae blooms (HABs) are increasing due to warmer water temperatures caused by global warming. Many lakes and estuaries around the world, which provide drinking water for millions of people and support ecosystem services, already have toxic, food web-altering, hypoxia-generating blooms of harmful cyanobacteria. For example, in China, more than 60% of the lakes suffer from eutrophication and HABs (Shao et al., 2014). Climate change is severely affecting our ability to control these HABs, or making it near impossible (Havens and Paerl, 2015).

Poor water quality due to eutrophication (mostly from poor sanitation and poor nutrient management) is one of the most widespread problems affecting available water supplies, fisheries and recreational activities. For example, the estimated cost of damage caused by eutrophication in the United States of America (USA) alone is approximately US\$2.2 billion annually (Dodds et al., 2009).

Climate change is expected to exacerbate water quality degradation as a result of higher water temperatures, reduced dissolved oxygen and thus a reduced self-purifying capacity of freshwater bodies. As floods and droughts are likely to increase due to climate change, there are further risks of water pollution and pathogenic contamination caused by flooding or by the higher pollutant concentrations during drought.

Figure 4 Seasonal variability



Note: Seasonal variability measures the average within-year variability of available water supply, including both renewable surface and groundwater supplies. Higher values indicate wider variations of available supply within a year.

Source: WRI (2019). Attribution 4.0 International (CC BY 4.0).

Nature-based solutions (NBS) can be implemented to better adapt to climate change, to increase the efficiency, effectiveness and robustness of water management infrastructure (including their operation and maintenance), and to contribute to climate change mitigation.

Evidence suggests that investment in NBS remains well below 1% of total investment in water resources management infrastructure (WWAP/UN-Water, 2018).

Wastewater management

Water and wastewater utilities are reportedly responsible for between 3 and 7% of GHG emissions (Trommsdorf, 2015), but these estimates do not include emissions associated with discharging untreated sewage. Indeed, untreated wastewater is an important source of GHGs. Given that, in developing countries, 80–90% of the wastewater is neither collected nor treated (Corcoran et al., 2010; WWAP, 2017), the emissions related to the water supply and sanitation sector – and its potential to contribute significantly to climate change mitigation – should not be neglected.

The formation of CH₄ (methane) and N₂O (nitrous oxide) in landfills, open sewers and lagoons amounted to an estimated 13% of global non-CO₂ emissions in 2005 (US EPA, 2012). Some 58% of these emissions stem from landfills, part of which is wastewater treatment sludge disposal (Guo et al., 2012).

Increases in wastewater discharge and fertilizer-rich runoff can lead to enhanced levels of eutrophication. The resulting methane emissions from lakes and reservoirs alone are estimated to increase by 30–90% through 2100 (Beaulieu et al., 2019).

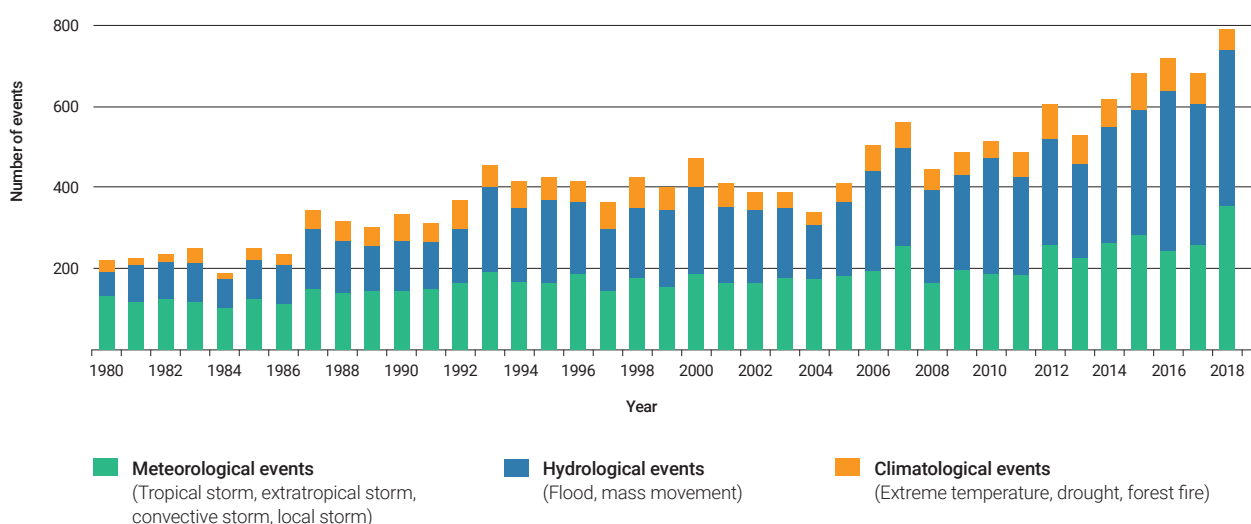
Water-related extremes and risk management

Floods and storms account for nearly 90% of the most severe natural disasters (Adikari and Yoshitani, 2009).

Changes in precipitation patterns under climate change conditions are expected to increase the intensity and frequency of flood and drought events in many regions (Hirabayashi et al., 2013; Asadieh and Krakauer, 2017).

Global floods and extreme rainfall events have surged by more than 50% this decade, and are now occurring at a rate four times higher than in 1980. Other extreme climatological events such as storms, droughts and heatwaves have increased by more than a third this decade and are being recorded twice as frequently as in 1980 (EASAC, 2018). Figure 5 shows the increasing trends in flood-related disasters globally, as well as meteorological and climatological events.

Figure 5 World weather-related natural catastrophes by peril, 1980–2018



Note: Accounted events have caused at least one fatality and/or produced normalized losses ≥ US\$100K, 300K, 1M, or 3M (depending on the assigned World Bank income group of the affected country).

Source: Munich Re, NatCatSERVICE (2019).

Around 74% of all natural disasters between 2001 and 2018 were water-related and during the past 20 years, the total number of deaths caused only by floods and droughts exceeded 166,000, while floods and droughts affected over three billion people, and caused total economic damage of almost US\$700 billion (EM-DAT, 2019).³

Droughts accounted for 5% of natural disasters, affecting 1.1 billion people, killing 22,000 more, and causing US\$100 billion in damage over the 20-year period (1995–2015). Over the course of one decade, the number of floods rose from an annual average of 127 in 1995 to 171 in 2004 (CRED/UNISDR, 2015).

The number of deaths, people affected and economic losses significantly varies annually and by continent, with Asia and Africa being the most impacted on all counts (Figures 6, 7, 8).

During this century, flooding from the rising sea level and storm surges will threaten the viability of some islands as well as some major deltas, such as the Nile and Mekong River deltas (WWC, 2009). In addition to direct impacts, this will also have severe impacts on water supply and sanitation infrastructure.

There is growing evidence that high-mountain areas are warming faster than lower elevations (Pepin et al., 2015). This elevation-enhanced acceleration in warming makes mountainous areas exceptionally vulnerable to climate change. This is most obvious from the impact on mountain glaciers and snowcaps, which show a decreasing trend almost everywhere in the world (Huss et al., 2017), affecting water resources for downstream populations (Immerzeel et al., 2019).

When economic prosperity is impacted by rainfall, episodes of droughts and floods, this can lead to waves of migration and spikes in violence within countries – 18.8 million new internal displacements associated with disasters were recorded in 135 countries and territories in 2017 (IDMC, 2018). Moreover, water scarcity is likely to limit the creation of decent jobs, since about three out of four jobs constituting the global workforce are dependent on water (WWAP, 2016).

Climate change and human health

At the end of the Millennium Development Goals period (2000–2015), 91% of the global population used an improved drinking water source and 68% used improved sanitation facilities (WHO/UNICEF, 2015). Much remains to be done to reach the new, higher levels of safely managed water supply and sanitation services as defined under the Sustainable Development Goals (SDGs) for the 2.2 billion and 4.2 billion people respectively who lack this superior level of service (WHO/UNICEF, 2019).

Inadequate water and sanitation have been conservatively estimated to cause nearly two million preventable deaths worldwide annually, as well as 123 million preventable Disability-Adjusted Life Years (DALYs),⁴ with the greatest burden falling on children under five (WHO, 2019a).

Even considering only a subset of the health risks, and making optimistic assumptions about economic growth, climate change can be expected to cause an additional 250,000 deaths yearly by 2030 by hampering the progress that is being made against killers such as undernutrition, malaria and diarrhoea (WHO, 2014).

The capacity of disease vectors to spread infectious diseases (including malaria, dengue, West Nile and Lyme disease) is increasing as rising water temperatures will increase the range of favourable breeding sites. Insect and animal vectors may allow them to travel to areas such as Europe and North America, which were previously too cold to support transmission (WHO, 2018b).

Undernutrition is anticipated to be one of the greatest threats to health resulting from climate change. It is projected that 540–590 million people will be undernourished at a warming of 2°C, with the young and the elderly particularly affected (WHO, 2018b).

Climate change is considered to be a poverty multiplier, which could force 100 million people into extreme poverty by 2030 (WHO, 2018b).

The World Health Organization (WHO) estimates that universal access to safe water and sanitation would result in US\$170 billion of economic benefits each year from reductions in healthcare costs and increased productivity from reduced illness (WHO, 2012).

To achieve the water–sanitation–hygiene (WASH) component of SDG 6 by 2030, it is estimated that capital investment needs to triple (to reach US\$1.7 trillion), and operating and maintenance costs will be commensurately higher (Hutton and Varughese, 2016).

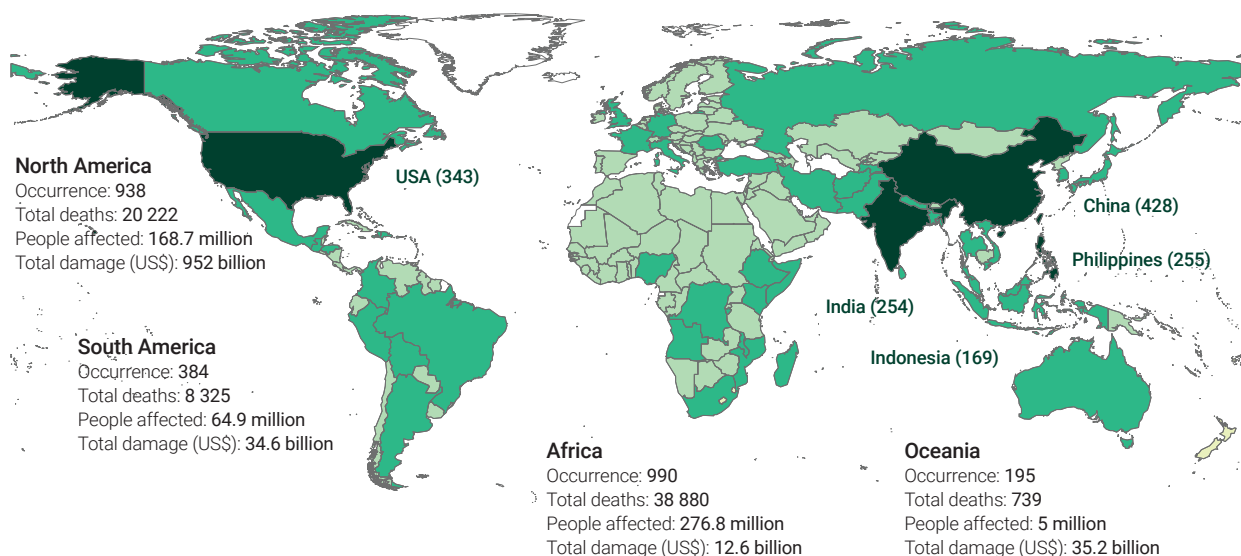
³ CRED's Emergency Events Database (EM-DAT) is used here to provide global, continental, national or regional disaster statistics.

⁴ DALYs is a measure of overall disease burden, expressed as the number of years lost due to ill health, disability or early death.

Figure 6 Spatial distribution of water-related disasters (droughts, floods, landslides and storms), 2001–2018

Number of water-related disasters

- 1–31
- 32–169
- 170–428

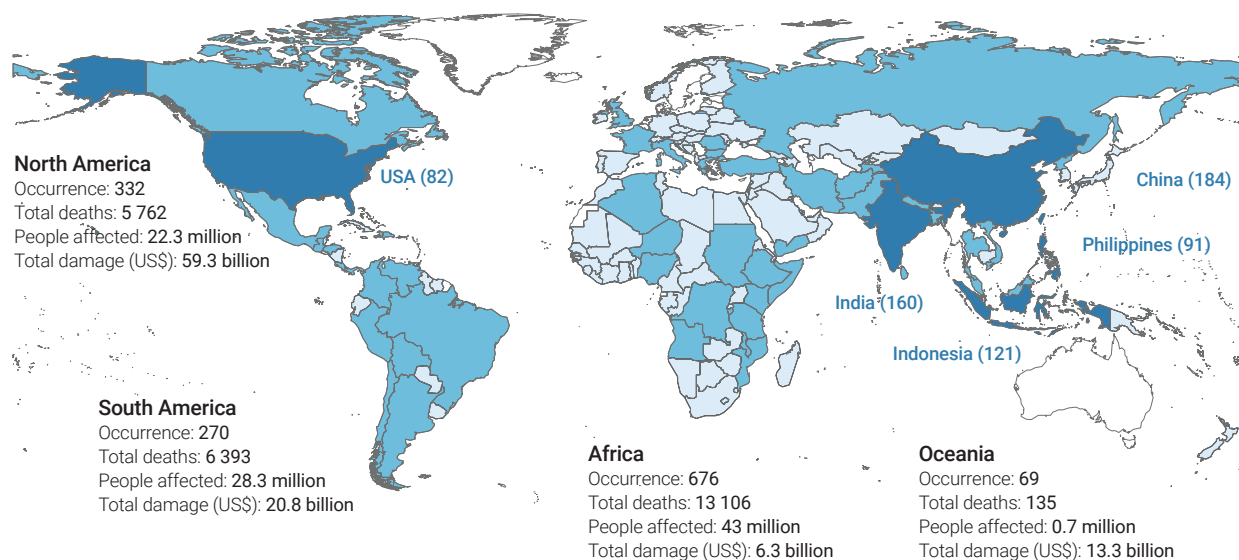


Source: Developed by UNU-INWEH, based on EM-DAT data.

Figure 7 Spatial distribution of floods, 2001–2018

Number of floods

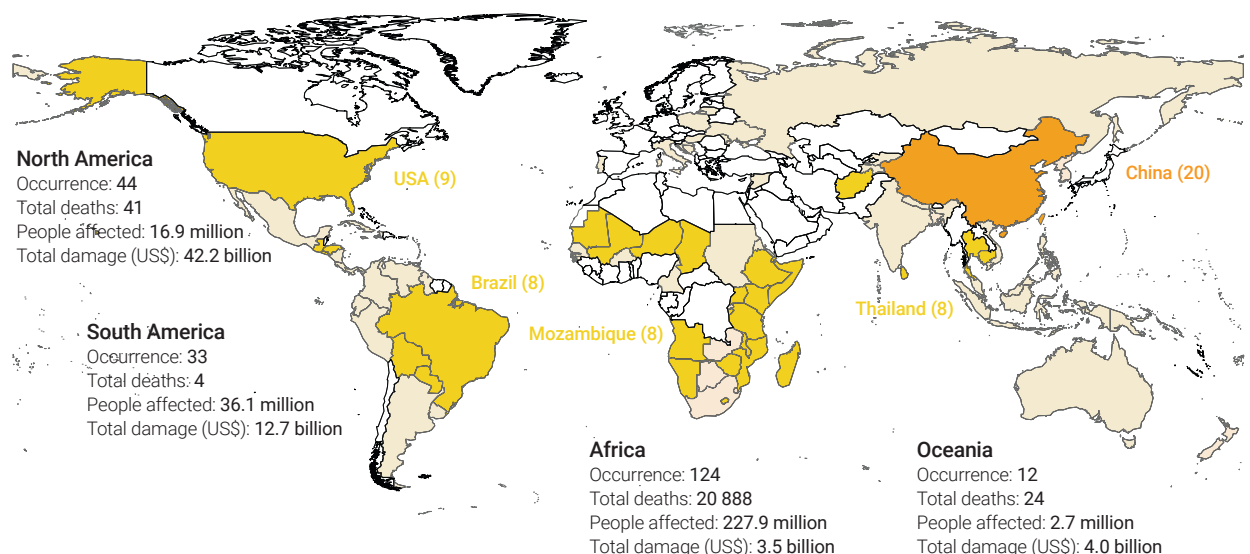
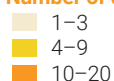
- 1–18
- 19–66
- 67–184



Source: Developed by UNU-INWEH, based on EM-DAT data.

Figure 8 Spatial distribution of droughts, 2001–2018

Number of droughts



Source: Developed by UNU-INWEH, based on EM-DAT data.

Agriculture and food security

In the face of competing demands, there will be little scope for increasing the amount of water used for irrigation, which currently accounts for 69% of all freshwater withdrawals (AQUASTAT, n.d.). The Food and Agriculture Organization of the United Nations (FAO) estimated a 5.5% increase in irrigation water withdrawals from 2008 to 2050 (FAO, 2011a).

Convergent results are showing that climate change will fundamentally alter global food production patterns as a function of water availability. Crop productivity impacts are expected to be negative in low-latitude and tropical regions but somewhat positive in high-latitude regions (FAO, 2015a).

Irrigation land is where the impact of elevated temperatures and aridity will be felt most. Although the current extent of this type of land (about 3.3 million km²) accounts for only 2.5% of the total land area, it does represent 20% of cultivated land and generates some 40% of the global agricultural output (FAOSTAT, n.d.).

The FAO has projected that an estimated US\$960 billion of capital investment is needed to expand and improve irrigation until 2050 in 93 developing countries, compared to the 2005–2007 levels of investment (Koohafkan, 2011).

Agriculture, forestry and other land use is estimated to account for 23% of total anthropogenic GHG emissions for the period 2007–2016 (IPCC, 2019b).

The relative share of agriculture's GHG emissions has dropped from an estimated 30% at the end of the 20th century to about 20–25% in 2010, largely due to high increases in emissions from the energy sector (FAO, 2017a). Nonetheless, net agricultural emissions are expected to grow further.

Avoiding the loss and waste of food provides a path to reducing GHG emissions. An estimated 25–30% of total food produced is lost or wasted across all stages of the food supply chains (FAO, 2013b; IPCC, 2019c). As food waste decomposes, it releases GHGs.

Between 2010 and 2016, global food loss and waste contributed 8–10% of total anthropogenic GHG emissions⁵ (IPCC, 2019c), a ratio that could rise above 10% by 2050 (Hiç et. al., 2016). Reducing food waste could also have significant repercussions on water (and energy) demand, thus providing a means of adaptation (relieving water stress) and mitigation (through reduced energy use).

The largest mitigation potential from forestry is expected from reducing emissions attributable to deforestation and forest degradation. More than 90% of national REDD+ results (United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries) reported to the United Nations Framework Convention on Climate Change (UNFCCC) come from reduced deforestation (FAO, 2016a). In the long term, progressive carbon sequestration from afforestation and reforestation is expected to maintain a similar level of mitigation (Griscom et al., 2017).

The impacts of climate change on the availability of water resources over space and time will affect the poor disproportionately through their effects on agriculture, fisheries, health and natural disasters. Nearly 78% of the world's poor, approximately 800 million people, are chronically hungry while two billion suffer micronutrient deficiencies (FAO, 2017a). They largely live in rural areas and rely mainly on rainfed agriculture, livestock or aquaculture to sustain themselves and their families – all of which are highly climate and water-dependent and therefore at risk to hydro-meteorological irregularities.

As such, climate change is recognized as an obstacle to ending rural poverty. With 80% of the impacts of drought absorbed by rural producers, the pressure on local water resources and reliance on water-lifting technology in particular is expected to increase (FAO, 2019).

Energy and industry

Global energy demand is projected to increase by more than 25% under the International Energy Agency (IEA) New Policies Scenario. However, the demand would be about double if it were not for improvements in energy efficiency (IEA, 2018).

Industry (including the energy sector for thermoelectric and nuclear power plant cooling) withdraws 19% of the world's freshwater resources (AQUASTAT, n.d.) (see Figure 1), and more recently energy alone was estimated as taking about 10% (IEA, 2016).

The industry and energy sectors' share in global water demand has been projected to grow to 24% by 2050, with the biggest absolute increases in Asia and Europe (mainly for industry), and North America being the only region predicted to show a decrease (Burek et al., 2016). Projections by the IEA anticipate that global water consumption by the energy sector will increase by nearly 60% (IEA, 2016) by 2040. In water-stressed areas this will contribute to increasing scarcity, as less water will be returned to the hydrological cycle for other sectors to use.

Industry has a particular and significant contribution to make in reducing water use and becoming more water-efficient. Data indicate opportunities for industry to decrease water consumption overall by up to 50% (Andrews et al., 2011 as cited in WBCSD, 2017).

While the 10% of water withdrawn globally for energy may look small compared to agriculture, this quantity is still considerable. A saving of 1% per year by better energy use or efficiency could provide water for 219 million people based on 50 L/day, depending on location and other factors. This offers an important opportunity for the energy sector to combat water scarcity while mitigating climate change (United Nations, 2018a).

While creating about 25% of the world's gross domestic product (GDP) and employment, industry also produced (in 2014) about 28% of global GHG emissions (with CO₂ comprising over 90%), and between 1990 and 2014 industrial emissions increased by 69%.⁶ Ammonia, cement, ethylene and steel manufacturing produced nearly half of industry's CO₂ emissions (McKinsey & Company, 2018).

⁵ This estimate includes the GHG emissions related to the production of the food, as well as from the decomposition process itself.

⁶ The IEA reports that in 2016, industry's global CO₂ emissions would increase from 19 to 36% if emissions from the electricity it uses were reallocated to it (IEA, 2017b).

Energy is in the spotlight of climate change initiatives as about two-thirds of the world's anthropogenic GHGs come from energy production and use (IEA, 2015). Over 90% of energy's CO₂ emissions are from fossil fuels (IEA, 2015). Fossil fuels are primarily used in coal-, oil- and natural gas-fired thermal power generating stations, which are substantial users of cooling water and globally used 58% of total energy water withdrawals in 2014 (IEA, 2016).

Global decarbonization efforts could depend on how companies manage water (CDP, 2016). In 2016, the Carbon Disclosure Project (CDP) reported a cost of US\$14 billion from water-related impacts of climate change, a fivefold increase from the previous reporting year. Moreover, CDP analysed emissions reduction activities disclosed by companies and found that nearly a quarter (24%) of these activities depended on having a reliable supply of water for their success. These activities, which included improvements in energy efficiency and low-carbon energy purchases, could cut 125 million metric tonnes of CO₂ emissions annually – equivalent to closing 36 coal-fired power plants for a year. Furthermore, over half the companies reported lower GHG emissions through improved water management.

The most promising direction is the increased use of low-carbon renewable energy technology with little water requirements, such as solar photovoltaic (PV) and wind. It has been estimated that in 2030 these renewable energy sources could be responsible for about a 50% reduction in water withdrawals in the United Kingdom, over 25% in the USA, Germany and Australia, and above 10% in India (IRENA, 2015).

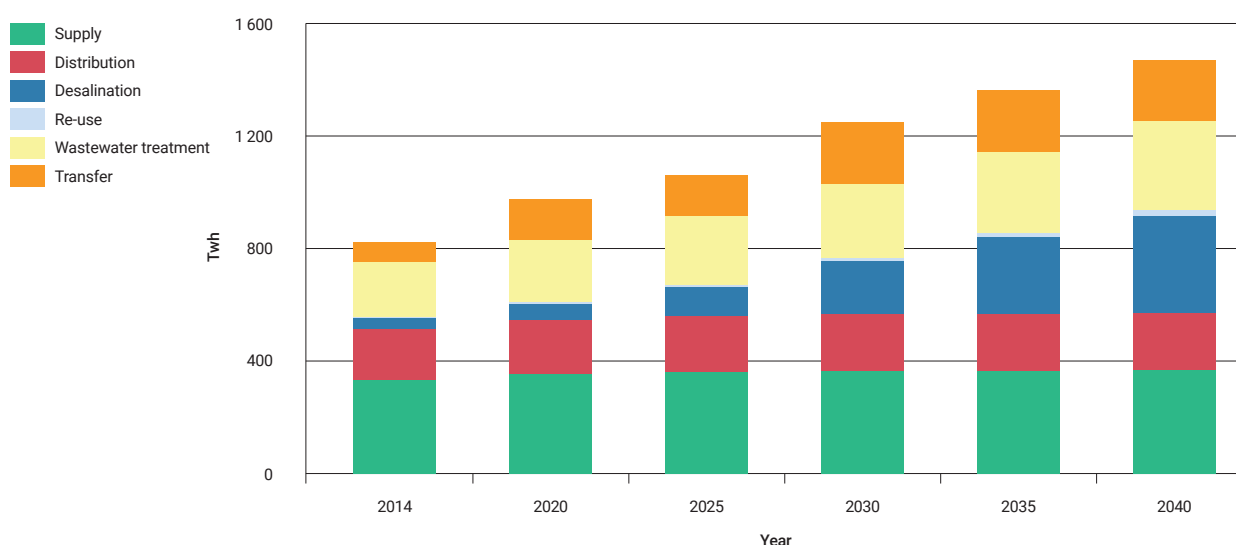
In the European Union, it was estimated that wind energy in 2012 saved as much water as used annually by seven million people in average households, and by 2030 – with increased deployment replacing some fossil fuel and nuclear generation – the amount of water saved will be approximately three to four times more (EWEA, 2014).

Climate change could produce a reduction in hydropower in the 2050s of 1.2 to 3.6%, especially in Australia and South America, and 7 to 12% in thermoelectric power in most regions (Van Vliet et al., 2016).

Electricity use by the water sector is mainly for the abstraction (40%), conveyance (25%) and treatment (20%) of water and wastewater, representing some 4% of global electricity production. Energy consumption in the water sector is expected to double through 2040, as a result of increasing desalination of seawater (Figure 9; IEA, 2016).

Increasing water use efficiency and reducing unnecessary water consumption and water loss both translate into lower energy use and thus lower GHG emissions. It has been estimated that the water sector worldwide could reduce its energy use by 15% until 2040 (IEA, 2016).

Figure 9 Electricity consumption in the water sector by process, 2014–2040



Source: IEA (2018). All rights reserved.

Human settlements

A majority of the world's population (4.2 billion out of 7.6 billion in 2018) live in cities. Projections of human settlements in the future (with a world population of 8.6 billion in 2030 and 9.8 billion in 2050) show that up to 60% of the world's population will live in cities by 2030, and 66.4% in 2050 (UNDESA, 2019).

In 2018, three times as many urban dwellers were estimated to live in the less developed regions than in the more developed ones (3.2 billion versus 1.0 billion), and this ratio is expected to rise as the vast majority of urban population growth is expected to occur within the world's least developed regions (UNDESA, 2019).

About 50% of the world's urban dwellers reside in settlements with fewer than 500,000 inhabitants (UNDESA, 2019). Many of these cities are vulnerable to the impacts of climate change.

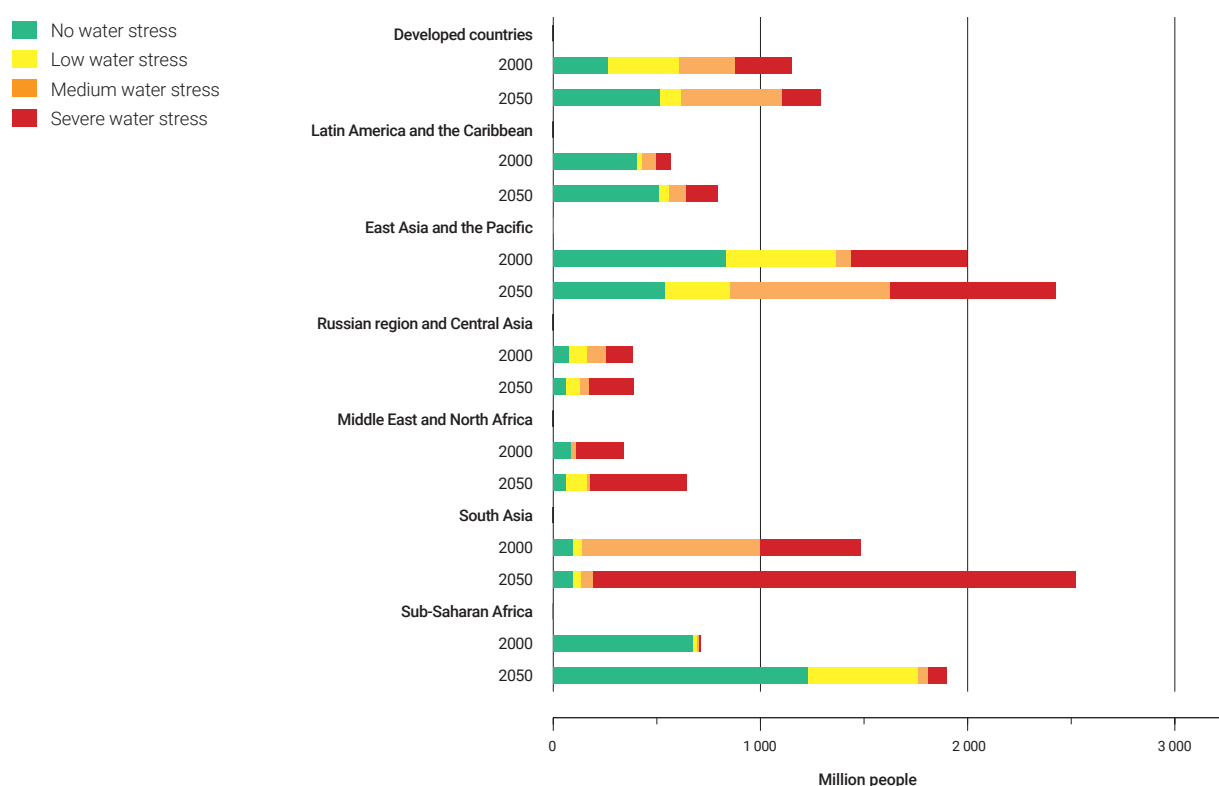
While climate change is already significantly impacting water resources, the demands of increased population and urbanization will further exacerbate water stress (defined here as a water exploitation rate of more than 40%) in many basins across the world, particularly those in densely populated areas in developing economies. By 2050, 40% of the world's population is projected to live under severe water stress (Figure 10), including almost the entire population of the Middle East and South Asia, and significant parts of China and North Africa (PBL Netherlands Environmental Assessment Agency, 2014).

It is estimated that by 2050, 685 million people living in over 570 cities will face an additional decline in freshwater availability of at least 10%, due to climate change (UCCRN, 2018).

Population growth and economic development were the dominant drivers of increases in the numbers of people affected and economic losses suffered due to coastal and river floods (PBL Netherlands Environmental Assessment Agency, 2014).

About 50% of Asia's population (2.4 billion people) reside in low-lying coastal areas. The rising sea level will intensify the flood-related impacts of extreme climate events (UNESCAP, 2018).

Figure 10 Number of people living under water stress under the Baseline Scenario*



Note: *The 'Baseline Scenario' stems from the third *Environmental Outlook* published by the Organisation for Economic Co-operation and Development (OECD, 2012). It assumes that no new policies are introduced and provides a benchmark against which the different policy variants are assessed.

Source: PBL Netherlands Environmental Assessment Agency (2014, fig. 2.6, p. 21). Attribution 3.0 Unported (CC BY 3.0).

Regional perspectives

As 60% of global freshwater flows cross national boundaries, transboundary cooperation is essential for effective measures towards climate change adaptation (UNECE/INBO, 2015).

Sub-Saharan Africa

Impacts of climate change on Africa's water resources are already acute. Numerous studies find that rainfall in southern Africa has decreased recently, probably as a result of climate change (IPCC, 2014a; Bellprat et al., 2015; Funk et al., 2018; Yuan et al., 2018).

The impact of population increase will be particularly pronounced on the African continent, where the population has been predicted to grow by more than half a billion by 2050, increasing water stress, particularly in urbanizing regions (Taylor et al., 2009).

Water-related impacts of climate change on human health are also expected, through vector- and waterborne diseases (including by further challenging access to safe drinking water, sanitation and hygiene) and via malnutrition, given expected impacts on food security (IPCC, 2014a).

Regional interdependence through hydropower in shared basins is high. By 2030, 70% and 59% of hydropower capacity in eastern and southern Africa, respectively, to be located in one cluster of variability, increasing risks of concurrent disruption to power generation (Conway et al., 2017).

Europe, Caucasus and Central Asia

Climate projections indicate increasing precipitation in northern Europe and decreasing precipitation in southern Europe. A marked increase in high-temperature extremes, meteorological droughts and heavy precipitation events is projected, but with variations across Europe.

Uncertainty is higher in Central Asia, with spatial variation in historic trends and inconsistency in projected changes for both precipitation and dryness/droughts.

The Intergovernmental Panel on Climate Change (IPCC) highlights increasing challenges for irrigation, hydropower, ecosystems and human settlements in the Europe region (IPCC, 2014a). The possibility for both floods and droughts to amplify health challenges, such as water-related diseases, is also a key issue for the region (UNECE/WHO Regional Office for Europe, 2011).

Latin America and the Caribbean

Changes in climate variability and extreme events already severely affect Latin America and the Caribbean.

In Central and South America, streamflow and water availability changes are observed and projected to continue, affecting already vulnerable regions. In South America, retreat of the Andean cryosphere will change seasonal streamflow distribution. The IPCC predicts with high confidence that water supply shortages will increase in already vulnerable semi-arid regions, with reduced precipitation and increased evapotranspiration, affecting cities, hydropower generation and agriculture (IPCC, 2014a).

In the Caribbean subregion, drought risk is projected to increase, especially if temperatures rise with more than 1.5°C. The Caribbean islands also face threats from sea level rise, including salinization, flooding and pressure on ecosystems (IPCC, 2018b).

Over 80% of the region's population lives in urban areas (UNDESA, 2019), and droughts have been linked to reduced employment and labour incomes in Latin American cities (Desbureaux and Rodella, 2019).

For example, in 2014, a significant increase in the number of Guatemalans seeking access to the USA coincided with the onset of El Niño-related drought conditions in the Central American Dry Corridor (Steffens, 2018). Climate change is expected to intensify drought risk here, forcing more poor rural families to migrate out of the region (UNECLAC, 2018).

Asia and the Pacific

This region is highly vulnerable to climate-induced disasters and extreme weather events, which are disproportionately burdening poor and vulnerable groups (UNDRR/UNFCCC/UN Environment Regional Office for Asia and the Pacific, 2019).

In August 2017 alone, intense monsoon rains affected 40 million people in Bangladesh, India and Nepal, claiming nearly 1,300 lives and putting 1.1 million people in relief camps (UNESCAP/ADB/UNDP, 2018).

Floods could cost South Asia as much as US\$215 billion each year by 2030 (UNESCAP/ADB/UNDP, 2018).

Climate change and increasing demand for water will put stress on the region's groundwater resources, as the availability of surface water is affected by increasing climate variability. Groundwater use in the region could increase by 30% by 2050 (ADB, 2016). The increase in demand for irrigation has already led to severe groundwater stress in some areas, especially in two of Asia's major 'food baskets' – the North China Plain and Northwest India (Shah, 2005).

In the area of investment, an estimated incremental investment of US\$21–47 billion by 2030 is needed to make water and sanitation infrastructure climate-resilient across Asia and the Pacific (UNDRR/UNFCCC/UN Environment Regional Office for Asia and the Pacific, 2019).

Western Asia and North Africa

Vulnerability to climate change is moderate to high across the region, with a generally increasing gradient from north to south.

The Regional Initiative for the Assessment of Climate Change Impacts on Water Resources and Socio-Economic Vulnerability in the Arab Region (RICCAR) projects largely decreasing precipitation trends across the region until the end of the century. Runoff and evapotranspiration generally follow the same trends as precipitation, although evapotranspiration is limited by water scarcity constraints in some areas.

Temperatures in the Arab region are increasing, and under a high-emissions scenario are expected to continue to increase until the end of the century to up to 4–5°C above their preindustrial levels (FAO/GIZ/ACSAD, 2017; UNESCWA et al., 2017).

The World Bank has identified Western Asia and North Africa as the regions facing the greatest economic threats from water scarcity exacerbated by climate change – costing up to 6% of GDP by 2050 (World Bank, 2016a).

Financing

In order to meet the first two targets of SDG 6 – access to safe WASH services for all by 2030 – capital investments must reach US\$114 billion per year. This is about three times the current annual capital investment levels in WASH. In addition to the initial capital inflows, significant resources are required to operate and maintain water and sanitation infrastructure and sustain universal coverage. These costs are recurrent and will outweigh the capital costs by 1.4 to 1.6 times by 2029 (Hutton and Varughese, 2016).

The above expenditures do not include the costlier Targets 6.3 through 6.6 of SDG 6, which include improving water quality, increasing the proportion of treated wastewater, increasing water efficiency, implementing integrated water resources management, and protecting and restoring water-related ecosystems. It also does not explicitly include climate-resilient technologies. Thus, without significantly increasing the levels of investment in water, it will be “*nearly impossible*” to reach SDG 6 (Fonseca and Pories, 2017, p. 8).

Since water is a critical factor of production in many sectors, increasing scarcity and vulnerability of water supplies would threaten livelihoods around the globe. Water-related losses could send some regions “*into sustained negative growth*,” with growth rates in some regions at risk of declining by 6% of GDP by 2050 (World Bank, 2016a, p. vi). These changes will burden poor households the most.

Out of the US\$455 billion climate finance invested in 2016, US\$11 billion went to water and wastewater management in climate adaptation, and US\$0.7 billion to water and wastewater management in climate mitigation (CPI, 2018). Increasingly, however, the mitigation potential of water management options is being recognized.

The World Bank estimates that improving water resource management could accelerate growth in some regions of the world by 6% (World Bank, 2016a). Various water-related climate adaptation policies can also provide co-benefits such as job creation, improved public health, promotion of gender equality, reduced household expenses and carbon sequestration, among others.

Development banks have begun to prioritize climate change and integrate it into their development activities, and some have climate-specific funds. Water managers could look to these funds, which in 2016 provided US\$51 billion, or 11% of all climate financing (CPI, 2018).

Pioneered in 2007, green bonds and climate bonds offer “*significant global opportunities to mobilize capital at scale for low carbon, climate resilient infrastructure and development efforts*” (World Bank, 2018c).

Gender

Although climate change affects all groups in society, the magnitude of impacts on women and girls will be much greater, increasing gender inequalities and threatening their health, well-being, livelihoods and education. In times of drought, women and girls are likely to spend longer periods of time collecting water from more distant sources, putting girls’ education at risk because of reduced school attendance. Women and girls are exposed disproportionately to risks of waterborne diseases during floods due to a lack of access to safe water, the disruption of water services and increased contamination of water resources.

Climate change will also jeopardize the livelihoods of women farmers in developing countries who depend heavily on access to water resources for food and crop production. Women make up on average 43% of the agricultural labour force in developing countries (Oxfam International, n.d.), as compared to about 35% in Europe (Eurostat, 2017) and 25% in the USA (USDA, 2019). The proportion can be much higher, such as in Kenya, where about 86% of farmers in 2002 were women (FAO, 2002). The out-migration of males can lead to an increased role of women in agriculture in terms of greater workloads (Miletto et al., 2017; FAO, 2018a).

Integrating gender in early warning systems is important, as women and children are reportedly 14 times more likely than men to die during a disaster (UNDP, 2013). They also play a pivotal role in emergency preparedness and responses as well as in disaster risk reduction (UNDRR, 2015b), provided they are empowered to do so.

Since 2000, progress on mortality associated with all major water- and sanitation-related diseases has shown an encouraging downward trend (WHO, n.d.) commensurate with advances in access to improved water supply and sanitation. However, morbidity has been slower to decline and, in many regions, the social and economic burden of inadequate WASH lies disproportionately on women and girls (e.g. lost opportunities for work or education due to water collection tasks or shame and anxiety about toilet use and menstrual hygiene management) (Wendland et al., 2017).

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