

UN-Water Policy Brief
CLIMATE CHANGE AND WATER

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Key messages

The global climate crisis is inextricably linked to water. Climate change increases variability in the water cycle, inducing extreme weather events, reducing the predictability of water availability, affecting water quality and threatening sustainable development, biodiversity and the enjoyment of the human rights to water and sanitation worldwide.

Growing demand for water increases the need for energy-intensive water pumping, transportation, and treatment, and has contributed to the degradation of critical water-dependent carbon sinks such as peatlands. And, some climate change mitigation measures, such as the expanded use of biofuels, can further exacerbate water scarcity.

National and regional climate policy and planning must take an integrated approach to climate change and water management. Increased water stress and meeting future demands will require increasingly tough decisions about how to allocate water resources between competing water uses, including for climate change mitigation and adaptation. If we are to create a sustainable future, business as usual is no longer an option and water management needs to be scrutinized through a climate resilience lens.

We need more investment in improved hydrological data, institutions and governance, education and capacity development, risk assessment and knowledge sharing. Policies need to ensure the representation, participation, behavioral change and accountability of all stakeholders, including the private sector and civil society. Adaptation plans need to incorporate targeted strategies that assist lower-income populations – those who are disproportionately affected by climate change impacts – to navigate new conditions.

There are significant co-benefits to managing climate and water in a more coordinated and sustainable manner. Solutions for addressing these integrated challenges are available and being implemented by a growing number of countries and international river basins.

Meeting the climate challenge means:

1. Acting now:

Uncertainty about the future cannot be an excuse for inaction today; if the world is to limit global temperature increases to well below 2°C, we must act immediately. Securing water for communities, economies, and ecosystems is critical for poverty reduction, green energy transformation, and creating a buffer from natural disasters. Climate policy must address water across all sectors of the economy and the environment to ensure a climate-resilient and sustainable future for all.

2. Considering water as part of the solution:

Improved water management, including sanitation, is an essential component of successful climate mitigation and adaptation strategies, as called for in the Paris Agreement. Water is also key to attaining the goals of the 2030 Agenda for Sustainable Development and the Sendai Framework for Disaster Risk Reduction. For these reasons, climate resilient water management can act as a mechanism of coherence between these global frameworks.

3. Improving water management practices:

As countries begin to review and implement their national plans in the context of the Paris Agreement, there is a unique opportunity to improve and enhance water management practices in ways that will allow communities, countries and basin authorities to make confident, risk-informed decisions that can help increase climate resilience, improve ecosystem health, and reduce the risk of water-related disasters.

4. Ensuring transboundary cooperation in adaptation:

Transboundary cooperation is needed to address climate impacts that cross national boundaries (i.e. drought, flooding of transboundary rivers, etc.), to avoid maladaptive consequences from a basin perspective and also harness the potential co-benefits of improved regional cooperation, such as reduced uncertainty due to exchange of data, peace and stability, enlarged planning space and shared costs and benefits.

5. Rethinking financing:

Climate finance for water resource management and sanitation supports community climate resilience, job creation at local level through green works, and helps to improve sustainable development outcomes. Innovative, blended finance solutions for water and climate, such as green and blue climate bonds, can help to leverage climate investment across the economy. Barriers to increased access to climate finance, such as lack of capacity and lack of institutional coordination, must be urgently addressed.

0. Introduction

Water is a precondition to life on earth and is essential for sustainable development. Since July 2010, safe and clean drinking water and sanitation are human rights, essential for the full enjoyment of life and all other human rights.ⁱ Water – including sanitation – is critical for socio-economic development, food security, healthy ecosystems and is vital for reducing the global burden of disease and improving the health, welfare and productivity of populations.ⁱⁱ

The science is clear: the global climate crisis increases variability in the water cycle, reducing the predictability of water availability and demand, affecting water quality, exacerbating water scarcity, and threatening sustainable development worldwide. These changes disproportionately affect poor and vulnerable communities and are compounded by a number of contributing factors, including population increase, unmanaged migration, land use change, reduced soil health, accelerated groundwater extraction, widespread ecological degradation and biodiversity loss. While all regions of the globe are affected, the impacts of climate change are highly variable and uneven. Some regions are experiencing extraordinary periods of drought, others increasingly severe and frequent floods and storms, while some face both sets of extremes. Slower onset impacts derived from accelerated sea level rise affect coastal areas, posing a particularly direct threat to small, low-lying island nations. At the same time, increased demand for water for energy, agriculture, industry and human consumption is leading to gradually more difficult trade-offs for this limited and precious resource, especially in areas of the world already facing water stress. For these reasons, it is often said that climate change is felt most directly through water.

Climate change represents both a profound threat and an unprecedented opportunity to invest in and transform our water governance and management systems so humanity can thrive in an increasingly uncertain and variable future. With respect to intergenerational justice, the global climate crisis raises particularly pressing issues, such as which risks society should be allowed to impose on future generations. Young people around the world are using their knowledge and innovation to offer solutions, raise awareness, protest for their rights and advocate for enhanced global action to address and combat the climate crisis and its consequences. As they correctly and urgently insist, the time to act is now.

1. Water and climate in the global sustainable development agenda

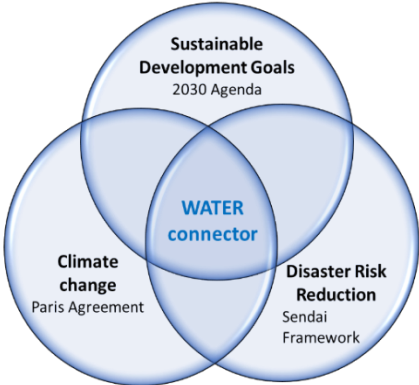
Over the last decade, over 90% of major natural disasters have been caused by floods, storms, heatwaves, droughts and other weather-related eventsⁱⁱⁱ that are expected to change in frequency and intensity as a consequence of climate change.^{iv} Against this background and with the aim to end all forms of poverty, hunger, fight inequalities and tackle climate change, countries adopted the 2030 Agenda for Sustainable Development in 2015. The 17 Sustainable Development Goals (SDGs) are interlinked and intended to support one another. For instance, sustainable management of water and sanitation (SDG 6) supports the attainment of the other 16 goals. Realization of SDG 6 and other water and ecosystem related targets are essential for society's health and well-being, improving nutrition, ending hunger, ensuring peace and stability, preserving ecosystems and biodiversity and achieving energy and food security. Water is also an essential component of national and local economies. Water management fosters gender equality, and social inclusion; and supports the creation and maintenance of jobs across all sectors of the economy.

Simultaneously, the United Nations Framework Convention on Climate Change (UNFCCC) Paris Agreement entered into force in 2016, addressing the need to limit the rise of global average temperature to well below 2 degrees Celsius above pre-industrial levels by the end of the century, as well as to adapt to the impacts of climate change. The Paris Agreement implementation phase, focuses on Parties working to define and enact their national commitments.

Also, in 2015 the Sendai Framework for Disaster Risk Reduction 2015-2030 was adopted at the Third United Nations World Conference on Disaster Risk Reduction in Sendai, Japan. The Sendai Framework includes seven targets and four priorities for action to reduce the occurrence and impact of disasters resulting from natural hazards. Among those priorities, the Framework calls for the strengthening and implementation of global mechanisms on hydrometeorological issues in order to raise awareness and improve understanding of water-related disaster risks and their impact on society, and advance strategies for risk reduction.

While these global agreements are discrete frameworks with their own sets of targets, mechanisms, and reporting requirements, they have overlapping agendas. With the clock ticking steadily towards 2030, there is urgent need to enhance action, coherence and coordination between them in order to reduce duplication or even triplication of effort, misalignment, and competition over funding. Given water’s inherent centrality to achieving these goals, it can play a connector role among them, reinforcing and strengthening each country’s commitments to mitigating and adapting to climate change, reducing disaster risks, ending poverty and inequality, and leaving no one behind.

A good example demonstrating this connectivity is the SDG 13: “Take urgent action to combat climate change and its impacts.” Given the fact that the impacts of climate change are deeply linked to water (e.g. floods, storms, droughts), many mitigation and adaptation measures include numerous water-based interventions. This further aligns with the Sendai Framework’s targets related to improving the disaster resilience of new and existing water infrastructure in order to provide life-saving, essential services both during and after extreme events (Target D and Priority 4).^v



Water is not explicitly mentioned in the Paris Agreement. Closer analysis, however, reveals the deep extent to which the Agreement is dependent on adequate water resources. Fresh, coastal, and ground water-related adaptation initiatives are included as a first priority in many Nationally Determined Contributions (NDCs). Yet governance mechanisms and methods for integrating water and climate remain largely absent.^{vi} The NDCs, together with other key national and multisectoral strategies such

as the National Adaptation Plans (NAPs), are a powerful framework for laying out national priorities for national climate action, with the potential to guide priorities such as building water climate resilience and to foster integrated management of resources.^{vii} They also provide a basis for investment plans that integrate climate vulnerability and resilience in the broader context of the SDGs and the Sendai Framework.

The following sections of this brief provide a solid background for why and how countries could consider water mitigation and adaptation interventions for the inclusion in NDCs, NAPs, National Communications and in other planning documents related to climate and water.

2. Observed and projected water-related climate impacts

Water is the medium through which many of the impacts of the climate crisis are felt by society; for example, through diverse impacts and risks to the energy, agriculture, health, and transport sectors. These are conditioned by interaction with non-climatic drivers of change such as population growth, migration, economic development, urbanization, environmental and land use or natural geomorphic changes that challenge the sustainability of resources by decreasing water supply or increasing demand.^{viii} Such interactions often result in uneven and unforeseen phenomena such as the recent advent of drought in the Netherlands, a low-lying coastal country far more adapted to life with floods. In other cases, it may be easier to identify hotspots for water-related climate impacts. This is the case of glacial meltwater, which is a critical water source, and an increasing threat, at certain times of the year for millions of people – for example those living in the Andean highlands of Bolivia, Chile and Peru.^{ix}

Worldwide an estimated 3.6 billion people now live in areas that are potentially water-scarce at least one month per year. That will increase to 4.8–5.7 billion people by 2050, according to the UN,^x creating unprecedented competition between water users— and across political boundaries. Sudden and slow onset disasters linked to the hydrological cycle have long been a major driver of forced migration as people move out of harm's way. Lack of access or availability of water – whether as a result of drought or the interaction of drought and deficient water governance – has also been considered a factor in the decision to migrate as they impact both well-being and livelihoods.^{xi}

The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) assesses hydrological impacts due to climate change. The 2018 IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels, provides mitigation pathways compatible with 1.5°C in the Context of Sustainable Development.^{xii, xiii} Both reports provide the most comprehensive information to date on observed and projected hydrological changes due to climate change including:

- Limiting global warming to 1.5°C above pre-industrial levels, compared to 2°C, can have huge implications on water resources as it may reduce the proportion of the world population exposed to a climate change-induced increase in water stress by up to 50%.
- Freshwater-related risks of climate change increase significantly with increasing greenhouse gas (GHG) concentrations. The most recent modeling studies estimate that for each degree of global warming, approximately 7% of the global population is projected to be exposed to a decrease of renewable water resources of at least 20%.
- Since the mid-20th century, socioeconomic losses from flooding have increased mainly due to greater exposure and vulnerability. Projections imply increasing variability in the frequency of floods. Flood hazards are projected to increase in parts of South, Southeast, and Northeast Asia; tropical Africa; and South America.
- Climate change is likely to increase the frequency of meteorological droughts (less rainfall) and agricultural droughts (less soil moisture) in presently dry regions over the coming decades. This is likely to increase the frequency of short or “flash” hydrological droughts (less surface water and groundwater) in these regions.

- Climate change negatively impacts freshwater ecosystems by altering streamflow and water quality, posing risks to drinking water even with conventional treatment. The sources of the risks are increased temperature, increases in sediment, nutrient and pollutant loadings due to heavy rainfall, reduced dilution of pollutants during droughts, and disruption of treatment facilities during floods.
- In regions with snowfall, climate change has and will likely continue to alter streamflow seasonality. Except in very cold regions, warming in the last decades has reduced the spring maximum snow depth and brought forward the spring snowmelt, leaving less snow in storage for dry summer months. Smaller snowmelt floods, increased winter flows, and reduced summer low flows have all been observed.
- Due to continued warming in glacier fed rivers, total meltwater yields from stored glacier ice will increase in many regions during the next decades but decrease thereafter.
- Increasing warming amplifies the exposure of small islands, low-lying coastal areas and deltas to the risks associated with sea level rise and saltwater intrusion into freshwater systems.

While these are relevant observations and projections, in many countries there is a gap in knowledge in terms of both observational data and in understanding how climate change will affect the hydrological cycle and water-dependent services at the appropriate temporal and spatial scales relevant to decision making. Major observational and data gaps include the impacts of climate change on water quality, aquatic ecosystems and groundwater conditions.

In the meantime, climate models continue to be refined and improved. Regional downscaling methods are now used to provide climate information at the smaller spatial scales needed for many climate impact studies, adding value both in regions with highly variable topography and for various medium-scale phenomena.^{xiv} However, probabilistic predictions related to precipitation and evapotranspiration remain poor, particularly at scales relevant to decision making. Strong interactions between multiple drivers combined with the intrinsic complexity of hydrological processes and systems make it difficult to precisely assess the full cascade of changes and their causalities. Conversely, when hydrological changes are detected, attribution of causes, including climate change, often remains uncertain. This uncertainty does not mean managers cannot make informed decisions. Rather, alternative, risk-based methods and approaches to assess and evaluate management options can be employed for a range of plausible future conditions. More on these approaches is included in section 7.

3. Mitigating climate change

The IPCC states that “the relationship between climate change mitigation measures and water is a reciprocal one.”^{xv} Measures introduced to reduce greenhouse gas (GHG) emissions have direct implications for water resource use and management. Conversely, water extraction and management measures have an impact on carbon emissions due to the energy intensity of water treatment and distribution systems. For example, GHG emission reduction activities often depend on a stable supply of adequate quality water while a recent assessment shows that over half of companies surveyed report that better water management is delivering GHG reductions.^{xvi}

The SDGs and NDCs both acknowledge the role that governments and other actors, including the private sector, must play in water stewardship in order to achieve a sustainable, low carbon future. However, this awareness is still incomplete. Few institutions and actors responsible for updating and implementing National Adaptation Plans (NAPs), NDCs and national climate change strategies have fully

taken water-related mitigation issues into account. Nor are the vast majority of companies following the example of forward-looking corporations in their approach to integrating water, energy, biodiversity and climate goals to minimize trade-offs and maximize synergies.^{xvii}

3.1. Mitigation Strategies

Mitigation strategies in the context of water can be broadly classified as nature-based or technology driven. Nature-based solutions (NbS) offer a vital means of moving beyond business-as-usual to address many of the world's water challenges while simultaneously delivering additional benefits vital to all aspects of sustainable development. NbS use or mimic natural processes to enhance water availability (e.g., soil moisture retention, groundwater recharge), improve water quality (e.g., natural and constructed wetlands, riparian buffer strips), and reduce risks associated with water-related disasters and climate change.^{xviii}

In NbS mitigation approaches, ecosystems act as carbon sinks, absorbing GHG emissions. Examples include preserving or restoring wetlands, reforestation of coastal mangrove forests, and natural flood plains in watercourses. Peatlands (peat soil and the wetland habitat growing on its surface) only cover about 3% of the world's land surface but store at least twice as much carbon as all of Earth's forests, while mangrove soils hold over 6 billion tons of carbon and can sequester up to 3-4 times more carbon than their terrestrial counterparts.^{xix} These linked hydrological and terrestrial ecosystems represent a major untapped resource for mitigation.

Compared to technology-based solutions to climate challenges, NbS are often lower cost and have multiple synergistic benefits for a variety of sectors. xx However, at present, water management remains heavily dominated by traditional, human-built infrastructure and the enormous potential for NBS remains under-utilized.

Technology-driven climate change mitigation options largely require investment in reducing emissions from powering water infrastructure, including for provision of drinking water, treatment of waste and storm water, and pumping water for agriculture and other uses. In this context there are different water and sanitation related mitigation strategies that ought to be considered for planning and management processes related to the extraction, distribution and treatment of water:

- Increased energy efficiency / use of renewable sources. Installing energy-efficient pumps and matching them to system requirements can save 10-30% of the energy demand in both water supply and wastewater treatment.^{xxi} Additional efficiency measures include:
 - Reduction of non-revenue water (NRW), i.e. leakage, metering errors and water theft
 - Metering of water consumption to manage demand
 - Water saving technologies especially in the agricultural and industrial sector
 - System monitoring and regulation, potentially with automation
 - Utilization of unconventional water resources, such as regulated treated wastewater for irrigation
- Production of renewable energy and recovery, reducing demand for fossil fuels:
 - Turbines placed along the water supply and wastewater system for hydropower generation (in the context of an integrated water resources management system that can identify whether particular developments are feasible and advisable)
 - Wastewater can be a cost-efficient and sustainable source of energy, nutrients, organic matter and other useful by-products.^{xxii} Biogas from wastewater treatment process can

be captured and contribute to carbon-neutral treatment. Also, given the temperature of wastewater, heat pumps can be installed in sewer pipes to produce energy.

Mitigation measures are often associated with co-benefits. For example, the strategies mentioned here can provide economic advantages for utilities such as the case of the treatment plant Strass in Austria that produces an energy surplus of 8%, turning a wastewater treatment plant into a power generator,^{xxiii} or the improved adaptive capacity of coastal communities associated with coastal mangroves (e.g. storm buffers and aquatic habitat protection). These benefits can drive additional investment in energy-efficient technologies. There are, however, tradeoffs associated with water related mitigation strategies as well, thus water impacts need to be considered when selecting mitigation measures, especially in water-scarce regions. For example, biofuels production can have negative impacts on water availability and demand as water resources for agriculture are becoming increasingly scarce in many countries as a result of increased competition with domestic or industrial uses. On-site sanitation facilities and wastewater treatment plants emit varying amounts of air pollutants (e.g. methane), therefore technology choice when planning service provision and management of systems has the potential to exacerbate or mitigate climate change. Hydropower reservoirs are considered to be major sources of low-carbon electricity that can be used to cut greenhouse gas emissions, but some reservoirs, for example those in tropical areas where the concentrations of organic matter are higher, emit global warming gases due to the decomposition of organic material in the flooded area (e.g. CO₂ and methane).^{xxiv} In most other conditions, however, reservoirs act as carbon sinks: absorbing more emissions than they emit.

Failure to consider the role of water in all mitigation (and adaptation) activities can reduce the effectiveness of these activities and increase the risk of maladaptation or outright failure. The goal is therefore to find the most appropriate blend of nature-based and technology driven investments to maximize benefits and system efficiency while minimizing costs and trade-offs.

4. Adapting to climate change

As has been recently noted, water is to adaptation what energy is to mitigation,^{xxv} meaning that reliable, clean water resources are essential in absorbing and adapting to changes brought on by the climate crisis. Over the past decade, water's centrality to climate adaptation has been increasingly recognized. Since the NAP process was instituted under the 2010 UNFCCC Cancun Adaptation Framework, Parties to the Convention have been formulating strategies and programmes to identify and address their medium- to long-term adaptation needs. Additionally, while it is not mandatory for Parties to include an adaptation component in their NDCs, most countries have chosen to do so. Even more encouragingly, over 90% of NDCs with an adaptation component refer to water.

While this is a positive development, there remains a concerning gap regarding *how* the NAPs and NDCs envision water governance for adaptation, in particular the incorporation and regulation of groundwater, as well as climate-resilient sanitation. Institutional reforms must be crafted accordingly, bearing in mind that local-level leadership is crucial for successful adaptation. In addition, the creation of local level management groups, such as water user associations (WUA) is an important instrument for cross-sectoral, horizontal and vertical coordination for the management of water resources and related adaptation strategies. Climate adaptation is at its core an iterative, context-specific, and cross-sectoral process for managing and transforming the risk of society and ecosystem collapse in the face of rapid and uneven change. Risks transcend boundaries, yet water is still largely perceived and managed as a stand-alone sector. Consequently, the cross-sectoral water demands of climate adaptation activities are

poorly accounted for in nearly all of the existing NAPs and NDCs, as well as other climate strategies and plans. Meanwhile both private- and public-sector mechanisms for tracking water use (i.e. national water accounting or corporate data on water use and discharge) across sectors remain rare. For example, the increased adoption of ecosystem-based adaptation such as reforestation or coastal restoration, while positive, has not included systematic accounting for the water needs of these measures, leaving them vulnerable to changes in water availability or demand.

4.1. Additional adaptation measures

- Climate-proof infrastructure. New and retrofitted water infrastructure is listed as a priority for adaptation action in over 68% of all NDCs.^{xxvi} Because climate change implies more variability and uncertainty in local and regional water cycles, water infrastructure must be both robust, meaning it can withstand a range of future conditions, and flexible, meaning that it can be modified or successfully adapted to change. Conventional, so-called grey infrastructure, with its high maintenance costs, relative immobility, and operational lifetimes in the 50-100+ year range is often neither robust nor flexible on its own.^{xxvii} This does not imply the need to abandon traditional infrastructure, rather the wider adoption of blended grey-green-blue¹ infrastructure, which can be more cost effective, less vulnerable to climate change, offer mitigation co-benefits and provide better service and protection over its lifetime.^{xxviii} The need for increased flexibility extends to institutions as well, for example, flexible operating rules for dam/reservoir systems to manage electricity generation, irrigation, and flood storage requirements across the system under a changing climate. Bottom-up approaches focusing on local engagement in climate-resilient infrastructure planning and development can also support the local economy and create jobs. It is important to note, however, that these considerations are site-specific and require local input and expertise.
- Preserve and protect aquifers. Aquifers comprise the world's largest source of freshwater available for human use and can be less vulnerable than surface water to the direct impacts of climate change. Thus, aquifers represent a key component in reducing the risk of short-term water shortage and increase water security through climate adaptation measures such as Managed Aquifer Recharge (MAR).^{xxix} However, storage capacity and recharge rates vary considerably, meaning that measures must be locally-adapted.
- Joint management of surface water and groundwater. Co-management can boost resilience to droughts and address water scarcity, making it possible to expand a region's overall water storage capacity. Conjunctive water management interventions such as managed aquifer recharge (MAR) and Underground Taming of Floods for Irrigation (UTFI) are sustainable, cost-effective and scalable solutions may be especially relevant in the developing-country context.^{xxx} MAR (through rainwater capture) is particularly pertinent in regions with uneven rainfall distribution to reduce the risks of extreme rainfall runoff and to store freshwater in the soil for the dry season. MAR is an important adaptation measure for Small Island Developing States (SIDS), which are among the most vulnerable communities to climate change and sea-level rise.
- Conserve, maintain, or rehabilitate wetland ecosystems. Wetlands play a crucial role, for example as a buffer against flooding and other extreme weather events, for filtering water etc. Wetland loss further compromises the future health and productivity of ecosystems and

¹ Grey infrastructure refers to entirely human-built 'hard' systems such as pipes, levies and concrete dams. Green and blue infrastructure includes natural elements such as a floodplain or coastal forest but can also be engineered by humans.

threatens biodiversity, altering the suitability of vast regions for food production and human habitation and contributes to global GHG emissions. Thus, their preservation and restoration is an essential component in an overall climate adaptation strategy.

- Understand water dependency and related climate risks. Cross-sectoral mechanisms that can account for the implicit and explicit water commitments across all parts and levels of society within and between countries – particularly in the context of understanding key hydro-climatic risks – to ensure that these activities are viable and do not undermine local water security, especially for vulnerable populations.
- Reduce urban and rural exposure. Policy interventions including integrated urban planning, risk management, expanded use of early warning systems, and community engagement can likewise reduce the exposure of cities to flood and drought risk. A special challenge is finding enough space to handle peak flows during (extreme) storm events and saving enough clean water to for use during dryer periods. This challenge call for solutions at different scales from the household level up to the city level. In rural areas, diversifying livelihood options, access to credit, securing land tenure, improving access to electricity and agricultural extension, as well as hydro-climate services, expanding crop insurance programmes can help rural communities to be more resilient to rainfall shocks and stressors.

5. Integrating approaches to managing water and climate change

Taking advantage of water’s potential to address both climate change mitigation and adaptation requires contending with new insights into two fundamental challenges: (i) that the past can no longer effectively predict the future, thereby introducing the challenge of confidence and uncertainty, and (ii) that most of the tools, infrastructure, and institutions currently used to interact with water assume conditions that are largely fixed and stable, locking in decisions for decades or longer, presenting the challenge of infrastructure inflexibility over relevant timescales.^{xxxii} These are not insurmountable problems but will require a significant transformation of the ways in which water is managed, both in terms of approach and scale. Integrated Water Resources Management (IWRM) must be coordinated across traditional sectoral, political and spatial boundaries^{xxxiii}.

The following sections lay out particular challenges and opportunities related to integrated water management.

5.1. Transboundary Water Management

Worldwide, 153 countries share rivers, lakes and aquifers, and 286 river basins and 592 aquifers cross sovereign borders.^{xxxiv} Transboundary basins account for an estimated 60 per cent of global freshwater flow, and are home to more than 40 per cent of the world’s population.^{xxxv} Transboundary cooperation in mitigation and adaptation is thus crucial to prevent possible negative impacts of unilateral measures, prevent maladaptation and to make mitigation and adaptation more effective, for example by reducing uncertainty through the exchange of data, enlarging the range and location of available measures and sharing the costs and benefits. It also helps prevent conflict, reduces existing knowledge gaps and promotes peace and regional integration, as well as wider economic development.^{xxxvi} River basin organizations play a crucial role in this.

To date, most existing transboundary water sharing agreements are relatively inflexible and do not account for climate variability or the need for adaptive institutions. Climate adaptation requires

extensive cooperation among neighboring states to manage rivers and aquifers impacted by climate change. Thus, the added adaptation benefits of transboundary cooperation and the risks of inaction need to be laid out in a way that drives demand for cooperation at the highest political levels.

As is suitable to the given context, transboundary cooperation should be emphasized in all steps of the climate change adaptation process: from collecting and sharing information (which form the basis of robust decision-support systems), developing joint vulnerability assessment, managing water with flexible and adaptive institutions, developing basin-wide adaptation strategies, to planning and operation of different adaptation measures such as infrastructure on shared waters.^{xxxvii} Basin organizations can even sometimes raise funds for adaptation measures across the basin. Joint data and knowledge sharing arrangements, as well as joint monitoring of basin conditions, are pre-requisites for successful transboundary cooperation in an era of climate change.

5.2. Nexus Considerations

There is no question of there being inextricable interlinkages or ‘nexus’ between water and economic sectors including energy and food (inclusive of agriculture), urban systems as well as landscapes and ecosystems. For example, as urbanization continues around the world resulting in higher population density and more intense land and water use, reserving urban land for flood alleviation (above or below ground) will likely lead to conflict with other stakeholders (housing, agriculture, etc.), which must be anticipated and addressed. For this reason, it is even more important to improve overall water resilience, due to the cascading effects it can have on people, economies and natural systems.

Climate change offers the opportunity to transform governance systems, management approaches, infrastructure, and financing mechanisms to acknowledge and account for the inherently cross-sectoral nature of water. Part of this transformation includes a need to merge top-down governance approaches with inclusive bottom-up, community-based decision-making that is responsive to local climate risks. An emerging community of practice around resilient water management is working around the globe to implement a growing suite of these risk-based approaches.^{xxxviii} While the nexus concept continues evolving, the following sections reinforce why an integrated approach to water is needed to maximize synergies and help mitigate and adapt to climate change in all sectors.

5.2.1. Water, Sanitation and Hygiene (WASH)

Climate change negatively impacts drinking water availability and quality, and the performance of sanitation, wastewater and hygiene services. For example, more frequent combined sewer overflows can flood and pollute low lying and / or densely populated areas and receiving waters, while drought can increase the use of poorly treated wastewater for peri-urban agriculture. Therefore, it is essential that WASH infrastructure and services are adapted to make them sustainable, safe and resilient to climate-related risks. At the same time ensuring investments in resilient WASH systems in areas identified at highest risk contributes to building community resilience to the impacts of climate change,^{xxxix} for example, by enabling access to water during times of scarcity, or reducing the risk of disease from faecal contamination of water during floods. Local implementation approaches are necessary to adapt WASH services to climate change and decisions should be based on the best available information for the relevant time period. For example, there may be limited value in scrutinizing climate projections to the end of the century for rural WASH programmes that prioritize household or community-based systems with a design life of a few years (e.g. pit latrines) or decades (wells, boreholes). In these cases, it is advisable to understand risk and base decision making on observed impacts of climate change at local

levels. Major investments in storm drains, wastewater plants and other big infrastructure projects – investments that are long-lived and inflexible – will require different analysis (inclusive of climate projections) and interventions.

5.2.2. Water and Health

The influence of climate change on the enjoyment of the human right to health is significant and varied. One of the primary impacts is the spread of infectious diseases, many of which are water-borne and already present a major burden for the most vulnerable populations worldwide. Water-borne diseases, such as cholera, are also highly sensitive to changes in temperature, precipitation and humidity.^{xi} Indirectly, climate change can reduce agricultural productivity, negatively influence nutrition, and increase the spread of foodborne illness. Increased incidences of extreme weather can intensify human exposure to water contaminated by agricultural runoff, flooded water and sewage treatment systems, and standing water (habitat for toxic algal blooms as well as a breeding ground for disease vectors that increase malaria risk) while drought can negatively affect water quantity and quality.^{xii} Drought also increases the entrainment of dust and fine particulate matter in the air, causing a variety of human health impacts, particularly for children and the elderly. These impacts are felt over a range of timescales, requiring advanced planning and adaptation measures that can respond to both short-term emergencies as well as longer-term stressors. Climate Resilient Water and Sanitation Safety Planning^{xiii} are relevant risk-based management approaches for managing health risks associated with climate variability and change.

5.2.3. Water and Agriculture

Climate change alters the frequency and intensity of rainfall, floods and droughts, causing significant impacts on agriculture and food production. While food shocks and stressors affect all people, women, Indigenous peoples, subsistence farmers, pastoralists, and fishers are disproportionately affected.^{xiii} In regions where basic food production and hunger are significant concerns, addressing climate adaptation — especially through water-related impacts — is essential to reduce long- and short-term threats to food security. Climate-resilient water resource management is a potentially powerful mechanism to achieve local, and potentially global, food security (encompassing food production, preparation distribution, consumption, and waste). On the mitigation side, interventions related to the increased utilization of solar pumps, practicing conservation agriculture (CA) to improve soil organic matter (needed for the soil to retain water), reducing post-harvest losses and food waste, and transforming waste into a source of nutrients or biofuels / biogas can address both food security and climate change. The food systems will also require need to produce more food with increased nutritional value, while becoming more efficient with regard to the use of resources including land, soil, water, energy and chemicals.

5.2.4. Water and Energy

Nearly all energy generation processes require significant water resources, while the abstraction, transportation, and treatment of water requires energy (e.g., electricity). Population and economic growth are simultaneously increasing energy and water demand, with global energy demand projected to increase roughly 27% by 2040^{xiv} and water demand expected to increase roughly 55% during the same time period (primarily from manufacturing, electricity generation and domestic use).^{xv} In addition, climate change and increasing hydrological variability will likely result in a heightened reliance on energy-intensive water supply options, such as transporting water long distances or desalination.^{xvi}

Renewables account for a growing portion of the overall energy supply mix and generally have a smaller water-footprint than their carbon-based alternatives. Thus, increased investment in renewables such as solar photovoltaics, wind, and small hydropower are needed to ensure that future energy and water demand can be met.^{xlvii} Integrated planning, regulation and management of the energy and water sectors at the national and basin levels can help to ensure that trade-offs are accounted for, synergies are ensured and that future demand for both can be met. As mentioned in section 3, efforts to reduce energy demand for water and water demand for energy should be considered, including alternative cooling systems or combined heat and power plants (CHP), as well as revised operations for new and existing hydropower plants.

5.2.5. Water and Ecosystems

The services ecosystems provide for climate change mitigation and adaptation, DRR, and sustainable development – for example, sequestering carbon in forests and peatlands, providing source water, nutrition, livelihoods, and medicine, and safeguarding communities from storms, floods, droughts and sea level rise through coastal forests and wetlands – are well recognized. However, these natural systems remain chronically underutilized and underfunded. At the same time, freshwater systems themselves remain under serious threat worldwide due to a complex set of drivers including urbanization, agriculture intensification and soil loss, over extraction of groundwater, and increased energy demand.^{xlviii} Climate change further complicates these interactions.^{xlix} For example, in some areas, insufficient water can turn carbon sinks into carbon sources,^l while in others, climate-induced changes to the natural flow regime of rivers can result in cascading impacts throughout entire ecosystems. Scaling up community-based natural resource management programmes, green job creation, and adopting governance mechanisms for protecting freshwater ecosystems need to be expanded. Ecosystem protection must be fully integrated into climate plans and policies and enforced at all levels. Application of such approach for transboundary basins is especially relevant since the basin itself constitutes a holistic ecosystem.

6. Climate finance for water

Under the Paris Agreement, developed countries committed to deliver at least \$100 billion from both public and private sources annually between 2020 and 2025 for both mitigation and adaptation projects. However, countries are now lagging far behind these commitments and there is no common formula as to how much of this sum individual countries should provide, or indeed what the contribution of public and private finance should be.^{li} Development banks, aid agencies, foundations, and a few commercial and private sector sources have tended to make up the bulk of what is generally considered climate finance. In addition, multilateral institutions such as the Global Environment Facility (GEF), Green Climate Fund (GCF) and the UNFCCC's Adaptation Fund have been used to directly fund climate change activities. National and bilateral climate finance initiatives represent an emerging source of funding in both developed and developing countries, though they remain focused predominantly on mitigation.^{lii} In recent years, the expanded use of verified green bonds such as the Climate Bonds Initiative's (CBI) Climate Water Bonds has signaled an increasing global appetite for municipal and private sector investment in debt capital markets for climate change. As of June 2019, approximately 8 billion USD in both grey and nature-based water investments have been certified.^{liii}

Elsewhere, The World Bank's Global Water Practice has developed an innovative methodology for their water portfolio that resulted in 2015 in the launch of a new programme called the Decision Tree Framework (DTF).^{liiv} The DTF is a stepwise guide to assess the climate risk level for all water-intensive investments and to gauge the level of effort necessary to reduce risks. It has now been applied to local-

scale facilities such as water utilities as well as basin-scale planning processes. The Hydropower Sector Climate Resilience Guide^{lv} offers a methodology for identifying, assessing and managing climate risks to enhance the resilience of hydropower projects.

Discussions around funding for climate change activities are largely centered on *how much* money is or ought to be available. The quantity of funding is certainly important, especially in countries and regions that are particularly vulnerable to climate change. However, the quality of projects funded is at least as important. Well defined, targeted finance processes can help mobilize new pools of resources and signal to public and private sector audiences why and how to ensure water and climate resilience.^{lvi}

The financial sector plays a larger role in climate resilience and water security beyond providing resources and measuring and managing climate risks in water-related investments. Insurance provision is a key role for the financial sector, helping to improve societal resilient to the impacts of climate change, especially those related to extreme water-related risks.^{lvii} Insurance can help reduce risk and incentivize disaster prevention through signaling (i.e., price setting). Regardless, some water risks will exceed society's risk reduction measures. For these residual risks, insurance plays a role in adaptation and recovery at multiple scales, from smallholder farmer crop insurance to multinational re-insurance.

Any water-related climate project must demonstrate a clear climate rationale. For potential recipients, such as water managers and river basin organizations, developing bankable projects necessitates working with their national climate change and climate finance colleagues. Additional inter-sectoral cooperation and specific capacity -building for water managers and basin authorities is thus necessary.

7. Actionable recommendations

In this brief, a number of recommended policies and actions for water-smart climate mitigation and adaptation measures, both within and across sectors, have been presented. Below are a series of broad recommendations for climate policy and decision makers to better integrate water into their plans and programmes.

7.1. Global and regional climate and water negotiations and processes

- Using existing fora such as the UNFCCC regional climate weeks or the NDC Partnership, facilitate the participation of a broader set of national and local government agencies and ministries, including water, health, energy and agriculture in global and regional climate events and workshops.
- Using agreed-upon scientific climate impact observations and projections, set criteria and develop a set of global priorities for climate-resilient water and sanitation interventions in specific “hot spots,” considering first the most poorly served, exposed and vulnerable rural and urban populations across the globe, as well as areas facing large-scale human displacement pressures.
- While continuing to support the refinement of climate change projections and downscaling of relevant climate information, support overcoming the “observation gap” among countries at different levels of development by financing the expansion of hydrological and meteorological observation networks so that climate information is available and exchanged within and between countries for better water management decisions.
- Develop regional and basin-wide adaptation strategies in order to maximize the effectiveness of adaptation and prevent negative effects of unilateral measures, empower basin organizations to address climate change.

- Ensure the role of water for mitigation is well represented in climate discussion and agreements as a mean to achieve GHGs reductions. This includes the restoration and preservation of degraded eco-hydrological systems. Water protection must feature as part of all climate change plans and activities, including national and regional development plans. Given its great potential for climate mitigation and adaptation, sanitation interventions need to be considered as well. Documentation of best practices and exchange of lessons learned around these areas should be promoted.
- Stimulate innovation and foster capacity building and better awareness of adaptive water management, including the importance and benefits of transboundary cooperation, assuring effective agreements and monitoring mechanisms, and service delivery options for climate change mitigation and adaptation.
- Enhance funding modalities within existing and new climate funds that are conducive to financing integrated approaches to building climate resilience through improved water governance and management, lowering administrative barriers to capacity-constrained countries and reducing transaction costs to facilitate coordination.
- Engage and empower youth and young water professionals – including indigenous youth – as leaders and knowledge holders that provide solutions for water security and climate action that respect, protect and promote the fundamental human rights to water and sanitation and facilitate intergenerational global governance processes as entry point for engaging youth as leaders in decision-making.

7.2. National and sub-national capacity building, planning, implementation and monitoring

- Update existing NDCs, NAPs and other national, subnational and local climate strategies to incorporate risk-based approaches to water provision and management practices that align with climate mitigation and adaptation targets, where appropriate.
- Establish/ strengthen a national-level mechanism to foster a closer dialogue between ministries of environment/ climate, water, energy, agriculture, planning, emergency response, and finance in the development, implementation and update of NDCs, NAPs and DRR plans.
- In coordination with line ministries including finance, support the integration of priorities highlighted in NAPs, National Communications and other national and subnational climate strategies into water and sanitation (including wastewater) sectoral strategies and plans with dedicated agreed budgets and water monitoring systems, and vice versa.
- Facilitate and expand cross-sectoral peer-to-peer knowledge and data sharing practices, so that new information and lessons-learned can be assessed considered and incorporated into management practice at all levels. The use of citizen science for collecting data and implementing projects on-the-ground should also be expanded.
- Facilitate institutional capacity building for the use of existing risk-based approaches to climate change mitigation and adaptation at the decision-making and project levels to ensure that decisions made now do not exacerbate future water stress for vulnerable and marginalized populations.

- Support academia to conduct research and collaborate with public and private institutions that invest in low-regret, climate-resilient and context specific water and sanitation infrastructure and technology.
- When targeting multilateral, bilateral and other sources of climate financing, ensure that proposals bring together cross-sectoral water considerations including sanitation (including wastewater) and hygiene, health, agriculture, energy and industry, and ecosystems. In-country capacity building to design and package compelling and fit-for-purpose climate resilient water investment proposals is also urgently needed.

It should be noted that while the above recommendations are directed primarily at climate policy and decision makers, water policy makers and practitioners will be needed to support these efforts with their experience and expertise, and will need to better coordinate their own plans and activities with ongoing climate change planning and implementation.

8. Conclusion

Freshwater is one of Earth's most precious resources without borders, sustaining ecosystems, economies, and society as a whole. The climate crisis is not the sole threat to freshwater. However, it further exacerbates existing conditions, making the management and management projection of future water availability and quality increasingly difficult, and demanding new strategies for managing this scarce and precious resource within and between the countries. Water is both an enabling and limiting factor in humanity's ability to mitigate and adapt to climate change. Risk- and ecosystem-based management approaches that ensure the meaningful and effective participations of affected persons allow for no or low-regret solutions that can be adapted over time as underlying conditions change. Improving the resilience of freshwater ecosystems is not only essential to adapting now; it is a moral imperative for the sake of future generations who did nothing to cause the climate crisis they will inherit. We have a unique opportunity to transform existing governance and management systems and to increase the coherence of the global frameworks society has instituted to bring about a sustainable future for all.

Uncertainty is no excuse for inaction: tools, methods and finance mechanisms are available now. We cannot afford to wait.

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