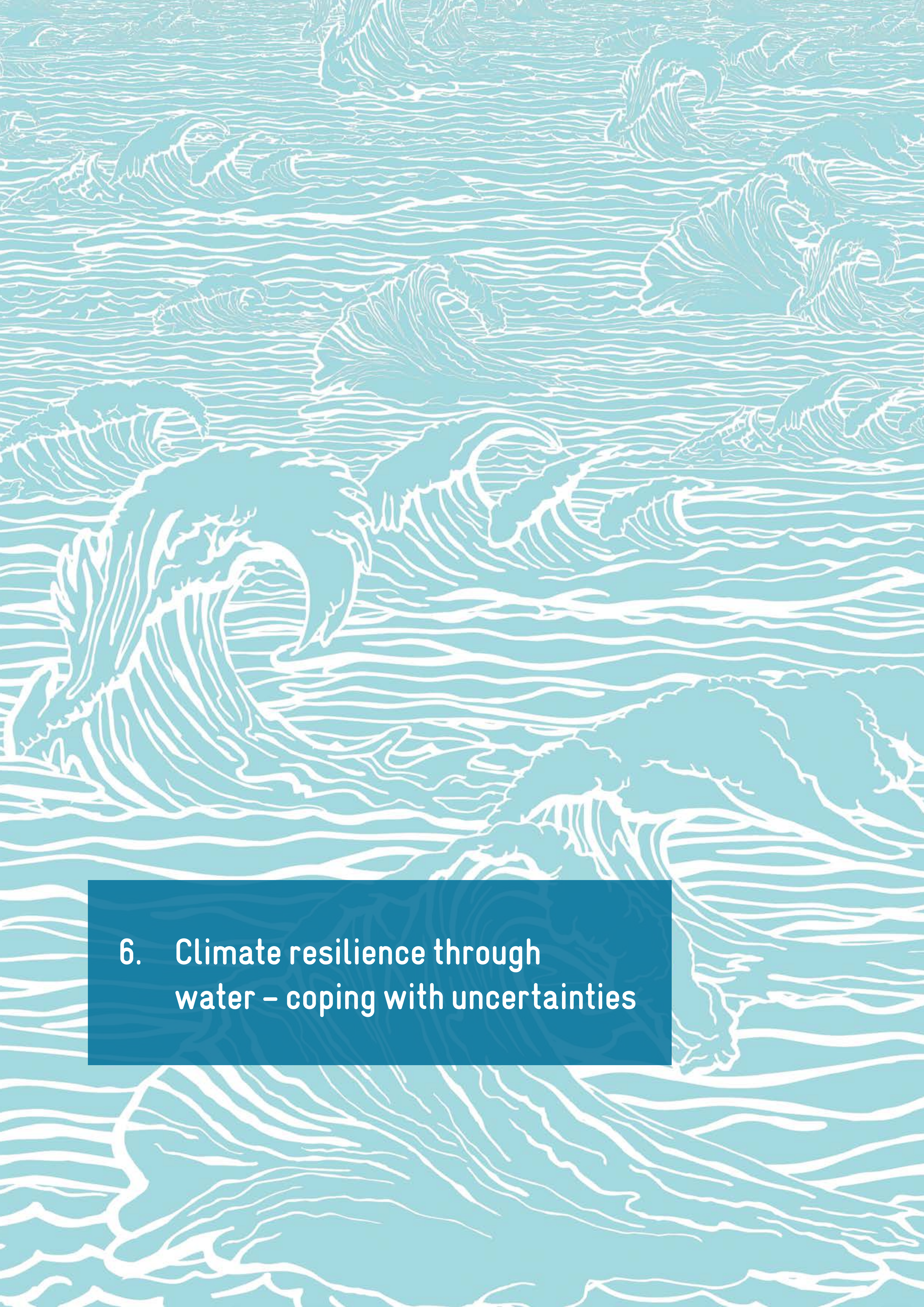


6. Climate resilience through water – coping with uncertainties

Humans experience climate change first and foremost through changes in the air and water, for instance through seasonal changes in precipitation, or through too much or too little water. The previous chapters have shown that even minor changes in climate can have profound impacts on the water cycle.

In turn, sustainable water management is essential for climate change adaptation strategies and their successful implementation, with positive effects in various sectors. Consequently, the water sector, including water resources management as well as water supply and sanitation, plays a crucial role in fostering the climate resilience of societies and ecosystems. Proven water sector concepts, such as improving water demand management, reducing water losses, and reusing treated wastewater, can effectively contribute to advancing climate resilience and might also help to reduce GHG emissions.

This chapter focuses on methods and concepts by and in the water sector that help to address water management issues, even if significant uncertainties about future conditions prevail.

Key Messages of Chapter 6

- Resilient water management is a prerequisite for successful climate change adaptation across sectors. Conversely, climate change impacts are likely to slow or undermine the progress made on safely managed water and sanitation.
- Depending on expected climate change impacts, different water management approaches, such as rainwater management and wastewater reuse, have proven to be effective and efficient in reducing vulnerabilities.
- Approaches that deal with uncertainties about future climate conditions need to be combined with socio-economic vulnerability assessments and water management knowledge in order to develop robust, but flexible water management solutions. Optimised and robust hardware to sustain shocks as well as adaptive management to withstand disturbances both increase the resilience of sanitation systems.
- Integrated water storage concepts, including groundwater, surface reservoirs, soil moisture and other elements, provide solutions to multiple climate change impacts and help to replace natural water storage threatened by climate change, such as glaciers and lakes.
- Healthy ecosystems are vital elements of climate resilience. Approaches that come with multiple co-benefits beyond climate considerations include Ecosystem-based Adaptation (EbA) and other Nature-based Solutions (NbS), for instance in the area of flood and drought risk management.
- Existing transboundary water cooperation mechanisms help to combine the long-standing experience of regional water management and governance with climate policy approaches. By more closely integrating water and climate interventions, decision-makers can help create synergies and co-benefits in transboundary basins. However, doing so will require upgrading existing transboundary water cooperation into Transboundary Resilience Management (TRM).

6.1 Cooperation across sectors

Water-related climate change impacts go beyond the water sector. For instance, climate change-induced water scarcity affects the availability of water for agricultural irrigation and cooling water for energy generation purposes. Developing efficient and effective climate adaptation (and mitigation) strategies will create challenges for the water, agriculture, health, energy, industry, and other sectors. Thus, one key governance challenge posed by climate change relates to the cross-sectoral nature of both climate vulnerabilities and adaptive responses. Successful cooperation among sectors, such as proposed by the **Water, Energy, Food Security Nexus (WEF-Nexus)** concept, is a prerequisite for implementing the adaptation actions in the following sections. Furthermore, the Integrated Water Resources Management (IWRM) process provides tools and approaches for cooperation across sectors and stakeholders and can be used in order to jointly improve climate resilience and decarbonization.

As the WEF-Nexus approach proposes, the conflicting interests and trade-offs between different actors and sectors will have to be successfully and equitably managed. It is also important to achieve synergies by identifying multiple benefits (co-benefits) for different sectors as well as adaptation and mitigation initiatives. This requires mainstreaming climate change aspects into the portfolio, and improving coherence between sector strategies and policies. Improved coordination, often the responsibility of environmental ministries, can facilitate the identification of trade-offs and synergies between sectors and their adaptation strategies.

In order to fully utilise water expertise to foster effective climate resilience, water activities need to account for essential climate considerations, including the following elements:

- Consideration of the specific climate vulnerability and risk context in the project design.
- Appropriately using available climate change and impact information, while clearly addressing related uncertainties.
- Designing water management measures in a way that they effectively and transparently increase the climate resilience of people and ecosystems.

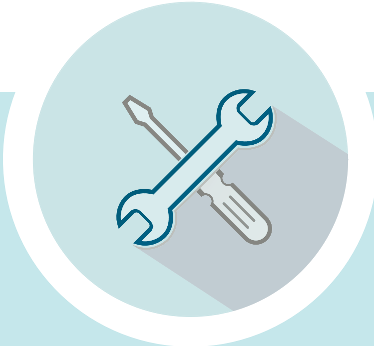
In order to coordinate the needs and interests of all stakeholders in a flexible and equitable way, policymakers can directly build flexibility into management instruments, such as sectoral water allocation or land use plans. To account for increasing variability, such plans should contain specific provisions for times of floods and drought. For example, decision-makers could shift water allocation from hydropower and irrigation to drinking water supply in times of water scarcity. Priority should always be given to foundational issues, such as the human rights to safe drinking water and sanitation.

The WEF-Nexus: A cross-sectoral approach

The scarcity of resources, such as water, land or energy, is a major constraining factor for sustainable development that can increase vulnerabilities to climate change and variability, and have immediate implications for local, national and regional security concerns. Interdependent and complex stakeholder constellations and competition over resources can spur scarcity, instability and conflict – potentially even forming a vicious cycle by mutually reinforcing each other. The WEF-Nexus approach fosters a paradigm shift away from separate, sectoral approaches towards holistically managed food, water, and energy sectors. The aim is to establish an integrated resource use approach based on horizontally and vertically integrated interventions. Thereby, the WEF-Nexus considers the totality of available sources of food, energy and water security to use resources more efficiently, while serving human and environmental needs through holistic, coordinated planning. A WEF-Nexus approach to resource use and project planning in a river basin avoids undesired impacts on other sectors, mitigates conflicts between them, and improves the efficient use of natural resources for human livelihoods while also ensuring ecosystem conservation.

Nexus platforms include the Nexus Regional Dialogues Programme (*www.water-energy-food.org*) which showcases concrete solutions to this integrated approach in five regions: Latin America and the Caribbean, Middle East and Northern Africa, the Niger Basin, Southern Africa and Central Asia.

Tools



Development of a specific analytical assessment tool through a WEF-Nexus approach

The link between natural resources and conflict is not as easy, straightforward and self-evident as popular discourses often indicate. Instead, water security and related risks (including those associated with food and energy security, which themselves heavily rely on water) as well as conflict, instability and insecurity each represent complex concepts. Climate change might make each of them – and the complex interdependencies they form – even more difficult to grasp and to control through means of management and governance.

In this context, GIZ has been commissioned by the European Union and the German Federal Ministry for Economic Cooperation and Development (BMZ) to implement the FREXUS project "Improving security and climate resilience in a fragile context through the Water, Energy and Food Security Nexus". Working in the Sahel region (Mali, Niger and Chad), the project aims at turning the vicious cycle of resource scarcity and conflicts over resources into a virtuous cycle of climate-resilient, secure and sustainable development through the application of nexus approaches at local, national and transboundary levels. In this context, it aims at enabling authorities and communities in fragile areas, who are facing the consequences of climate change, to tackle these issues in a peaceful, cooperative and integrated way. Such an approach requires the identification and understanding of vicious cycles, as well as the development of approaches to turn them into virtuous cycles. This provides the basis for further engagement of the FREXUS project in developing nexus-based action plans for climate-resilient resources management for conflict prevention and the promotion of peace.

GIZ is working with the Water, Peace and Security Partnership to further develop its analytical tools at both the global and local levels by integrating water, food and energy security concerns – especially in light of climate change and affiliated risks:

- **The global hotspot identification and early warning tool** aims at identifying areas that could suffer from natural resources-related conflicts in the future (water, energy and food security). The identification is based on the combination of different factors that typically determine whether natural resources-related challenges could lead to conflicts.

- **The local nexus and conflict analysis:** Once a hotspot has been identified, further analysis will be conducted through a localised zoom-in tool in order to identify the key drivers of conflict and develop adequate and problem-specific responses to them. To support decisions in the context of dialogue and decision-making – considered as key means for conflict prevention, mitigation and resolution – the analysis not only supports, but also relies on dialogue and participation with stakeholders. On top of that, the analytical tool will be adapted to new areas in Niger and Chad on a local level, as it has already been tested in Mali (Inner Niger Delta).

Implementing and strengthening a multi-level governance approach is key to delivering climate resilience

Finding the right climate adaptation solutions requires examining the specific local and regional contexts, but it also requires looking beyond administrative borders: the best solutions for increasing climate resilience, e.g. water storage options, such as afforestation in catchment areas, may be located in neighbouring administrative units (*see Chapter 6.6*). While implementing basin-wide strategies for climate adaptation may allow policymakers to efficiently address adaptation challenges, these strategies should be coordinated with national adaptation plans and account for international climate policy processes (*see Chapter 8*). It is therefore necessary to support effective governance mechanisms, not only for horizontal (across different sectors), but also for vertical (across different levels of administration) coordination and cooperation. Improving these mechanisms requires adequate governance capacities at all levels, including processes and institutional structures, as well as human capacity.

Criteria for climate-resilient water projects

Water-related activities can create co-benefits ranging from economic and social priorities (such as income opportunities) to health or economic development. Several additional aspects can help to establish a direct link between improving resilience to the impacts of climate change and potentially reducing GHG emissions. These include the following:

- Following a clear climate rationale in a resilience-building project.
- Basing projects on a proper assessment of climate risks and vulnerabilities to make adequate use of available climate information and, as appropriate, local stakeholder knowledge.
- Considering potentially negative effects on other sectors, societal groups, neighbouring communities or states, and taking a basin-wide perspective, as appropriate.
- Ensuring long-term flexibility in terms of adaptable water infrastructure, management solutions, governance structures and policy instruments.
- Involving adaptive governance approaches that include mechanisms for regular review and learning in order to adapt selected solutions to potentially changing conditions.
- Identifying and inducing multiple (co-)benefits, including GHG mitigation effects, as well as benefits in terms of biodiversity and sustainable socio-economic development.
- Ensuring alignment with national climate priorities, strategies, plans and overall development objectives.
- Considering gender aspects and the needs of vulnerable communities and ecosystems.

Involving the private sector in collective action for increased climate resilience

In some countries, more than 80% of critical infrastructure services (e.g. energy, water, sanitation, transport, food supply, etc.) are delivered by private actors (Schneider, 2014). Moreover, private actors, e.g. in the agricultural sector, determine both land-use and water-use efficiency. Private sector action can also have significant impacts on water-related ecosystems. In turn, climate change impacts on water resources are equally challenging for the private sector as for individuals, households and the public sector. Consequently, the private sector also needs to increase its resilience and adapt to changes. Furthermore, by investing in climate adaptation activities, the private sector can increase the resilience of surrounding communities and local governments (Schaer and Kuruppu, 2018).

➔ ***Private actors, including in the agricultural sector, are often among the largest water users. Their action can leverage water resilience.***

Moreover, private financial institutions and investors, such as banks, pension funds, insurance companies or impact investors, might invest in resilience or provide funding for others to adapt, e. g. through (micro-) loans, bonds or venture capital (Druce et al., 2016). In efforts to increase climate resilience, the water sector (and other sectors) can thus benefit from partnerships between the private and public sectors to support effective implementation. Existing approaches for involving the private sector in collective action are outlined in the boxes below.

Tools

Initiatives to address water risks involving all stakeholders – Water Stewardship approach

The private sector is increasingly aware of water risks. The Water Stewardship approach can be an effective means for non-state actors to overcome climate- and water-related challenges. It is a collaborative and multi-stakeholder approach that aims to achieve social, environmental and economic benefits.

Several Water Stewardship initiatives exist, such as the Alliance for Water Stewardship, the WWF Water Stewardship programme, as well as the Interna-tional Water Stewardship Programme (IWaSP) and its follow-up programme NatuReS (Natural Resources Stewardship Programme), funded by the German Federal Ministry for Economic Cooperation and Development (BMZ) and the UK Department for International Development (DFID).

Within the framework of these initiatives, several risk assessment tools have been developed. For instance, IWaSP prepared the Water Risk and Action Framework (https://ceowatermandate.org/wraf/about) that allows public bodies, private actors and civil society to jointly identify measures aimed at reducing shared water risks, including risks related to climate change. IWaSP initiated and set up partnerships between these three distinct stakeholders, and coordinates them with the support of GIZ bilateral and regional water programmes.

Considerable progress in Water Stewardship approaches has been made in recent years. However, in order to achieve further success, leading companies need to set an example and advance new approaches. Also, companies will need to mobilise new forms of finance, cooperate with peers, support suppliers, and drive coordination to the next level (Morgan, 2018).

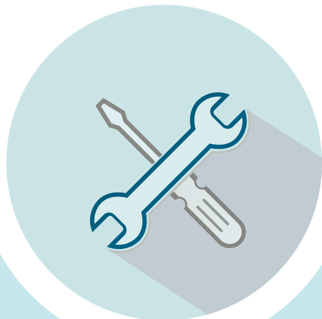
6.2 Risk-based management for dealing with uncertainties

The Global Risk Report of the World Economic Forum has counted water crises among the five top risks in terms of impact for nine consecutive years – also in its 2020 edition, where water crises was listed a top five risk, together with failure on climate action and extreme weather (World Economic Forum et al., 2020). This indicates a high level of awareness on water risks and calls for their appropriate management.

Although improved data, strengthened monitoring and better information exchange can help to reduce uncertainties in climate change projections to a particular degree (*see Chapter 3*), significant uncertainties and risks will remain. While decision-makers on water-related activities have always had to deal with climate variability and uncertainty, the combination of climate change and rapid demographic, economic, institutional, social and environmental developments is expected to increase uncertainty to an unprecedented level (Sadoff and Mueller, 2009).

In consequence, water management systems need to be designed in a way that ensures continuous performance, even under increasingly unknown future conditions. Thus, they need to include considerations of uncertainty and potential risks. A central step to ensuring a desired performance under unknown future climate conditions is to assess climate-related risks, that is, the likelihood that a certain impact resulting from climate-induced hazards will occur.

Tools



Private sector initiatives to address water risks – Water Risk Filter

Water risks can constitute a major threat for private actors. It is estimated that agriculture accounts for about 70% of global water withdrawals, mostly for irrigation. Users include smallscale farmers, cooperatives, private businesses, as well as large companies. The latter's water use can significantly affect water availability and quality for its own business continuity, as well as for societies and the environment. Industrial water use, including a large private sector share, accounts for another 20% of global water withdrawals (figures from WWAP/UN-Water, 2018).

Such a strong water dependency entails responsibility for sustainable water use, but also vulnerability to the water-related impacts of climate change and other trends. Even though private actors are increasingly aware of these water risks, appropriate water risk management know-how, guidelines and regulations are often missing.

In order to assist private actors in assessing and mitigating water risks, the World Wildlife Fund for Nature (WWF) and the German development finance institution DEG jointly developed the **Water Risk Filter**. The freely accessible online tool allows investors and companies from all sectors to assess and quantify water-related risks. The risk assessment considers the location of a company (basin-related risks) as well as its impact and performance based on several variables (company-/commodity-specific risk). The filter translates the underlying data sets into risk metrics. Several map layers visualise the specific risk dimensions. In another step, the tool suggests actions for risk mitigation and developing a water stewardship strategy.

https://waterriskfilter.panda.org (WWF and DEG, 2018)

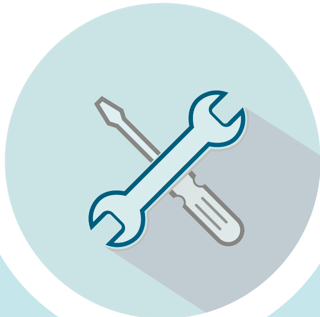
Risk and vulnerability assessments as baselines for monitoring adaptation effects

Appropriate risk assessments and management can help to define specific objectives to reduce climate risks, while elaborating measures to accomplish these objectives. In addition, it evaluates possible risks against costs for a range of different stakeholders (Hall et al., 2013). As a result, the consideration of risks is a crucial part of climate adaptation strategies – with a relevance for the water sector.

Thereby, risk and vulnerability assessments, involving the appropriate use of existing climate projections as well as the thorough consideration of climate-related risks and socio-economic vulnerabilities, provide a necessary foundation for sound planning of climate resilience measures and strategies. In addition, they help to set a baseline against which adaptation effects can be monitored and evaluated in the future.

The latter is important for tracking and assessing climate change adaptation activities and progress, eventually improving climate adaptation efforts by and in the water sector.

Tools



Standard Guidance on Climate Risk and Vulnerability Assessments

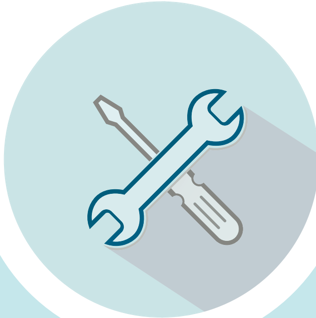
The IPCC has formulated a conceptual and widely recognised basis for identifying and dealing with climate risks in their reports. While the focus was originally on vulnerability, this was replaced by a focus on risks (with vulnerability being one of three elements), introduced with the 2012 Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX). It was then used in the IPCC's Fifth Assessment Report (AR5) (IPCC, 2014). Based on these concepts, experts have designed and applied comprehensive vulnerability and risk assessment approaches to provide decision-makers with a sound basis for policy making.

The IPCC has conceptualised risks as "the potential for consequences [= impacts] where something of value is at stake and where the outcome is uncertain […]. Risk results from the interaction of vulnerability, exposure, and hazard […]." This concept is also illustrated as part of the conceptual risk framework (see Figure 29 on the next page). It was informed by the risk concept of Disaster Risk Reduction (DRR) frameworks and puts a stronger focus on hazards and the role of uncertainty of the outcomes, also due to the interrelation of hazard and exposure of affected groups.

As outlined by the risk supplement to the vulnerability source book (published by GIZ in 2017), there is a need to specify the risk focus of an assessment as a starting point. Users need to identify the type of hazards and climate impacts that lead to risk – and who or what is at risk. One example for risks in this context is the risk of water scarcity for small-holder farmers.

There are several guidelines and handbooks that provide best practices for analysing vulnerability and climate risks (Morgan, 2011; UNEP, 2013a; Fritzsche et al., 2014). In recent years, efforts have focused on standardising assessment approaches to provide a sound basis for policies at all levels.

Tools



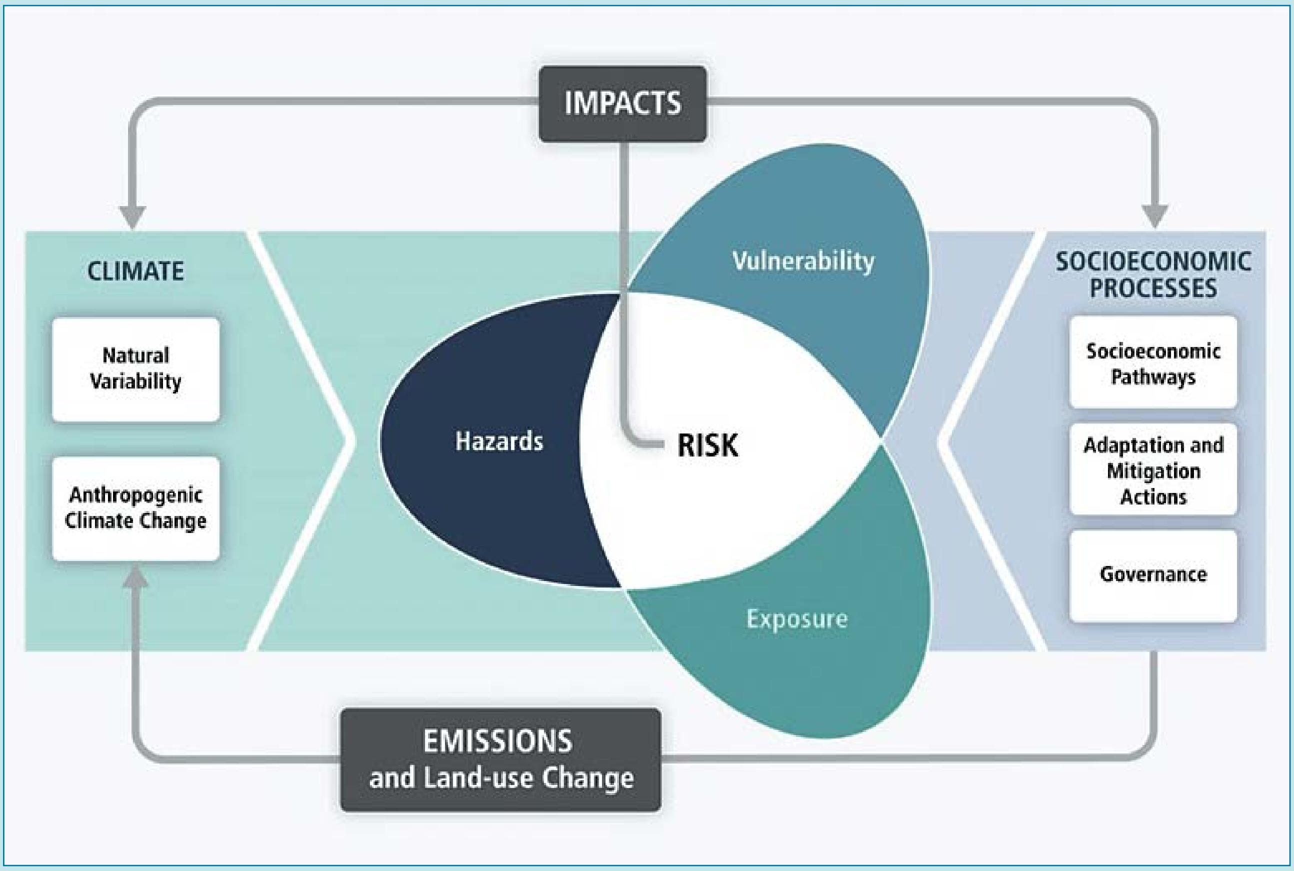


Figure 29: The IPCC AR5 conceptual risk framework; source: IPCC, 2014

Assessing climate-related risks

Assessing climate-related risks and finding robust solutions to increasing climate resilience is not only a technically complex task, but also a highly contextual one. Given the uncertainty associated with climate impact projections, it is difficult to identify an optimal adaptation solution. Furthermore, the question of which solution is best very much depends on stakeholders' risk perception and preferences. Decision-making in the field of climate adaptation requires difficult choices regarding the right policy instruments to support implementation, the right administrative level, geographical scale and timing to act – all in the face of multiple uncertainties. As a response to climate- related challenges, different approaches and assessments within the water sector have evolved over time. The most relevant challenges are:

A stationary approach in water resources management derives future seasonal water availability and occurrence of extremes in a certain region from experiences with hydro-climatic conditions in the past. Even though natural climate variability has always occurred, climate change and socio- economic developments constitute additional uncertainties in terms of factors influencing water availability and use in the future. This bears the potential to increase risks for water management, rendering stationary approaches more inadequate (Milly et al., 2008). New approaches have thus become necessary to assess how future risks affect the performance of water management systems (Hallegatte, 2009).

➔ ***Climate risk assessments have been applied since the 1990s.***

Unlike stationary approaches, newer concepts have started to consider potential future changes of climatic and hydrological conditions and affiliated risks. As a result, water planners have begun accounting for climate risks since the 1990s, including through **top-down climate risk assessments**. Traditional top-down climate risk assessments often begin with downscaling global climate models (*see Chapter 3.1*) to project how climate change will affect the water cycle in a specific region. The analysts then determine whether the performance of a specific water management system will still be acceptable under the modelled conditions. Thus, the assessment examines whether the system still complies with defined minimum standards, fulfilling social, economic, environmental and other benefits. Top-down approaches have proven useful for water-related analyses at the global or regional scale. However, their outputs often lack the required level of detail for local/site-specific water resources management or water infrastructure decisions (García et al., 2014). Therefore, they can only inform water management institutions and policy-makers to a degree of detail that is limited (Ray and Brown, 2015). Another drawback of top-down approaches is that uncertainties are transferred and possibly magnified from the global level to the multiple-model stages, as explained in *Chapter 3* (Matthews et al., 2015).

Bottom-up analyses and probabilistic approaches to climate risk assessments

Uncertainty about future conditions should not be used by decision-makers as an excuse to do nothing, while waiting for better information to become available. Planning documents should communicate transparently both existing uncertainties related to climate projections as well as socio-economic factors, with the aim of providing flexibility to adapting strategies as new information becomes available. Furthermore, the costs of inaction might be greater than any possible benefits that may result from delaying intervention until actors are better informed. Nevertheless, the presence of uncertainties and the corresponding need for adaptation measures that provide benefits under different climate scenarios are also no excuse for simply implementing standard water activities that have been used to deal with hydro-climatic variability in the past (Schiermeier, 2014).

Good practice example

Zambia: Lusaka Water Security Action and Investment Plan. Considering evidence-based climate variability

Supporting climate- and economically resilient cities: The rapidly growing demand for water by Lusaka's population and industry is fast exceeding what both the Lusaka Water and Sewerage Company (LWSC) and the local environment can currently supply. In addition to water supply challenges, there are issues with sanitation, (groundwater) pollution, wastewater, drainage and flood protection within the city. Furthermore, the impacts of climate change are leading to a more water-insecure future. Apart from a 1 to 1.5 degree increase in temperature, there are projections of varied seasonality, which is already being experienced. The city of Lusaka, in particular, is expected to receive reduced rainfall, but more frequent extreme weather events ranging from storms to droughts.

Currently, there is an absence of effective planning, and issues are dealt with as they arise. More cohesive planning, investment in infrastructure and overall management of the system and its governance could significantly help to improve water security and climate resilience. For this purpose, the Lusaka Water Security Initiative (LuWSI) and other partners have recognised the need to develop a concrete investment and action plan to address the city's water risks: the Lusaka Water Security Action and Investment Plan (WSAIP). WSAIP is funded by DFID with the objective of providing hydrogeological, economic and financial support to LuWSI, while at the same time contributing to stakeholder capacity-building and empowerment.

WSAIP has delivered:

1. Two visual online story maps that present the case for action and investments into water security in Lusaka.

2. An online digital atlas that contains important maps to support decision-making on water security in Lusaka.

3. A strategic framework explaining the rationale behind the Water Security Action and Investment plan and the selection process of the 27 projects and actions has been elaborated in 2-pagers and concept notes.

Apart from climate change and variability, the tools developed to determine the city's water security also take into account population growth, economic growth, infrastructure developments, and communities' activities influencing water insecurity and city growth.

In 2015, GIZ's IWaSP Programme initially hosted LuWSI's secretariat during its development phase and mobilised resources to work with actors from the public sector, private sector, civil society and international organisations towards carefully shaping LuWSI's governance and strategy, while initiating the first projects in parallel. The initiative was officially launched in December 2016.

It is evident that **bottom-up climate risk assessments** offer one response to addressing uncertainties and the inherent limitations of top-down assessments described above. While top-down approaches observe how selected future climate scenarios will affect a water system, bottom-up approaches (as defined in Ray and Brown, 2015) start by assessing the vulnerability of such systems. The vulnerability is determined by examining historical and recent data. Building on this information, analysts then tailor the information derived from GCMs based on what is needed to best inform decisions to reduce vulnerability. In the next step, this tailored climate information is used to evaluate if the water system's performance can be sustained under different climate and non-climate conditions in the future. Subsequently, analysts draw on tailored climate projections to assess the probability that these conditions will occur. Probabilistic (as opposed to deterministic) approaches allow analysts to quantify the uncertainty of assessments. This helps decision-makers to adjust their strategy depending on actors' willingness or adversity to take certain risks.

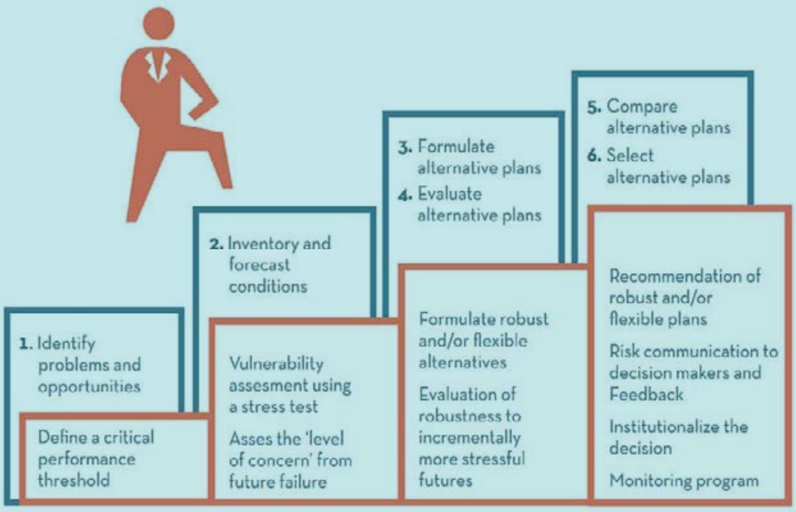
➔ ***Probabilistic approaches allow analysts to quantify the uncertainty of assessments.***

Decision-Scaling (Brown et al., 2012) is a known method for bottom-up climate risk assessments that has also been a core component of the World Bank's "decision tree" approach. Decision-Scaling was developed to assist water project planning through a pragmatic process for risk assessment (Ray and Brown, 2015). Decision-Scaling was also used in the recent Climate Risk Informed Decision Analysis (CRIDA) (Mendoza et al., 2018). CRIDA is explained in more detail in the box below.

Tools

The Climate Risk Informed Decision Analysis (CRIDA)

The Climate Risk Informed Decision Analysis (CRIDA) (Mendoza et al., 2018) is a bottom-up vulnerability assessment methodology. It was designed to evaluate various future uncertainties related to a changing climate, demographics, environment or economics for water resource planning and management. Through extensive stakeholder involvement, it seeks to find robust and flexible solutions, for example for droughts or water shortages, that are capable of reducing risks. This way, it also endeavours to support a paradigm shift in water resource planning and decision-making that focuses more on "what is known" (the risks) instead of "what is unknown" (the exact impacts of climate change).



The progressive and modular methodology includes several of the approaches mentioned in the present chapter and can be adopted to the demands of individual organisations or projects and their contexts. The application of CRIDA is particularly suited for developing countries and data-poor regions, as it uses local knowledge and stakeholder engagement at the early stages of engineering projects.

Figure 30: CRIDA tasks within a typical planning framework. Blue boxes show widespread planning framework steps; orange boxes show CRIDA steps. Source: Mendoza et al., 2018.

Robust and flexible solutions for risk management

The nature of managing climate change impacts means that not all climate risks and projection uncertainties can be eliminated, as discussed above. Therefore, to prevent prospective failures of water (management) systems, solutions developed to increase climate resilience will have to account for remaining uncertainties and residual climate risks. Even in areas where the impact of climate change can be projected with relatively high certainty, such as in the Mediterranean or the Blue Nile Basin, long-term water management investments (e.g. large infrastructure) will have to perform appropriately and sustainably under changing climatic conditions during their lifetime.

Climate-resilient water management entails developing **robust solutions** that perform well over a wide range of climate (and non-climate) scenarios. They are **designed flexibly** enough to be easily adapted to changing conditions if required; thus, they can take many forms.

➔ ***Robust solutions perform well over a wide range of scenarios.***

The Decision-Scaling approach introduced above is one way to develop robust solutions by assessing the vulnerability of certain solutions to various climate conditions. In order to account for various aspects of robust solutions, Hallegatte et al. (2012) have proposed the following typology:

- **Multiple-benefit solutions** (also refered to as co-benefits in the present study; sometimes also as no-regret solutions) provide benefits even in the absence of negative future climate change impacts. This applies especially to adaptation approaches that provide multiple benefits beyond climate resilience, such as water demand management to reduce pressure on scarce water resources as well as reducing costs for treatment and pumping. In this context, Nature-based Solutions (NbS) can be highly beneficial, for instance, the conservation of floodplains or other wetlands can strengthen flood protection, while creating co-benefits for biodiversity, human well-being or enhanced water storage capacities (*see Figure 32 on page 90*).
- **Reversible or flexible solutions** can be adapted to changing conditions at relatively low cost. Most governance approaches fall into this category. Examples include institutionalising the use of early warning systems or evacuation planning that accounts for climate risks, but also building modular infrastructures that can easily be amended or deconstructed.
- **Safety-margin approaches** base water management decisions on higher (or lower) targets than currently expected. This is especially important for decisions that are not reversible or flexible, such as the zoning of settlements in floodplains. In acknowledging the uncertainty inherent in climate projections, it might be wise to add a safety margin to areas considered prone to flooding, where settlement is prohibited.
- **Solutions that reduce decision-making time horizons** can increase robustness. For example, because uncertainty increases with the length of projections, and investments can have a long lifetime, it can be beneficial to choose solutions with shorter lifetimes like decentral solutions for water supply and sanitation or easy-to-retrofit or modular flood defence.

Good practice example

Using the Economics of Climate Adaptation (ECA) method to reduce climate risks in urban areas in Bangladesh

Bangladesh is among the most vulnerable countries to climate risks. While the North of the country is affected by long periods of drought, the southern coastal parts suffer from recurring floods caused by heavy rainfall, storm tides and cyclones. Together with a rising sea level, these trends contribute to the intrusion of salinity into inland water bodies, groundwater and soils. Therefore, people from rural areas seek refuge in cities, often finding themselves in slum areas of big cities, which are also exposed to the effects of climate change.

Barisal, the second-largest coastal town in the Southeast of the country, has experienced rapid population growth in recent decades (7.7% per year). It is estimated that more than 110,000 people live in slums. Canals and ponds are used as garbage dumps or have been filled in order to create more living space. About 150 km of water canals running through the city are dumped with garbage and rubble, increasing the risk of flooding.

With the help of the Economics of Climate Adaptation (ECA) method introduced by the reinsurance company Swiss Re, the damage caused by climate change can be determined, taking into account economic trends and population dynamics for future decades. The German development bank KfW has applied the method for a risk analysis in Barisal as part of a programme on behalf of the Federal Ministry for Economic Cooperation and Development of Germany (BMZ). The application resulted in the identification of cost-benefit priority measures for climate-resilient urban development, also considering socio-economic aspects, such as poverty and vulnerability. The resulting measures will be implemented in line with existing national adaptation strategies.

In order to decrease climate risks for the most vulnerable, the project's focus will be on expanding and increasing the capacity of the drainage network as well as on the renewal and elevation of low-lying sections of prioritised roads, which function as evacuation routes during extreme weather events. Including the population in the planning and implementation phases of the project ensures that ownership and identification with the programme are strengthened. The City of Barisal is given the opportunity to build up expertise within the framework of pilot projects and, at the same time, to increase its own personnel and financial capacities.

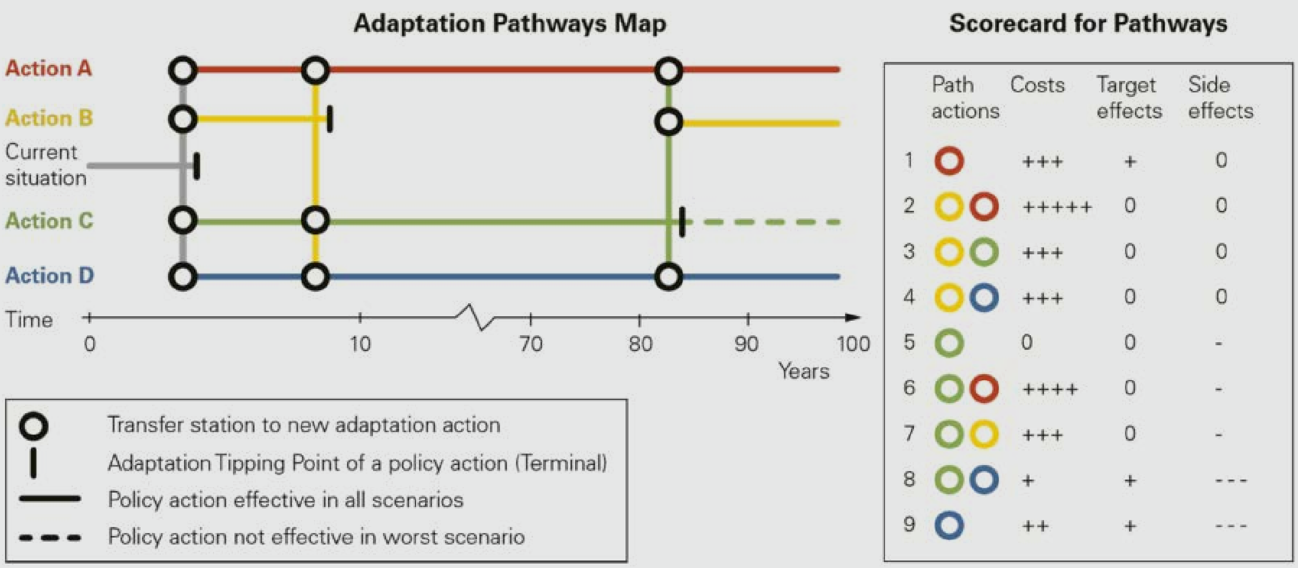
Adaptation Pathways

The long-term robustness of adaptation strategies can further be strengthened by embracing adaptive management approaches. **Adaptive management** allows shifting from one water management solution to another in order to account for altered conditions. For instance, such strategy adjustments could be based on a continuous iterative process of revising previously chosen solutions or learning from newly available information.

Adaptation Pathways are based on the premise that, under strong uncertainty, not all solutions can be known now, but they have to be flexibly identified and implemented over time. They constitute an adaptive – though structured – approach to adaptation planning (Haasnoot et al., 2013). Thus, Adaptation Pathways allow for the development of adaptive plans containing strategies and activities that can still be changed or adjusted in the future. As they enable prospective adjustments in the design of water actions, making use of adaptation pathways avoids "locking in" a single adaptation strategy to achieve pre-defined objectives, such as costs or benefits. A group of Adaptation Pathways are alternatives that can be implemented when pre-defined "tipping points" are reached by identifying the benefits and costs of each possible option at a given time (*see Figure 31*).

Already today, there are various practical examples of Adaptation Pathways being used by water actors: Among others, they have been used to help small municipalities to plan for future sea-level rise in Sweden (Carstens et al., 2019), to evaluate forest adaptation to climate change in England (Petr and Ray, 2017), to assess the performance of the municipal water system of Miami in the USA (Bouwer et al., 2018), and to determine long-term adaptation responses of the flood risk management system of the city Can Tho in Vietnam (Radhakrishnan et al., 2018). An example of an Adaptation Pathways diagram and a scorecard for each of the pathways is presented in *Figure 31*.

Figure 31: Example of an Adaptation Pathways diagram and a scorecard for each of the pathways. Source: Ray and Brown 2015.



In the figure, starting from the current situation, targets begin to be missed after four years; an adaptation tipping point is reached. Following the grey lines of the current plan, one can see that there are four options. Actions A and D should be able to achieve the targets for the next 100 years in all scenarios. If Action B is chosen, a tipping point is reached within about five more years; a shift to one of the other three actions (A, C, or D) will then be needed to achieve the targets. If Action C is chosen after the first four years, a shift to Action A, B, or D will be needed after approximately 85 years in the worst-case scenario (follow the solid green lines). In all other scenarios, the targets will be achieved for the next 100 years. The colours in the scorecard refer to the actions: A (red), B (orange), C (green), and D (blue). The point at which the paths start to diverge can be considered as a decision point. Taking into account a lead time e.g. for implementation of actions, this point lies before an adaptation tipping point. *Source: Matthews et al. (2015)*

Complex risks need collective action and appropriate governance

Finally, increasing climate resilience in the water sector regularly involves changing water allocations and water use practices, e.g. to ensure water security during drier periods and drought. It also often involves adjusting land use and agricultural practices, e.g. where floodplains are to be rehabilitated as part of integrated storage systems. Finding solutions for increased climate resilience therefore requires accommodating and balancing stakeholders' diverging interests. Many aspects of climate adaptation require collective action (Termeer et al., 2017) and thus the establishment of partnerships between the private and public sectors to support effective implementation (*see Chapter 6.1*). Adapting to climate change, while accounting for climate risks and and increasing climate resilience, thus remains a technically complex problem that requires appropriate governance and cooperation.

Good practice example

Applying a web-based tool for developing Climate Change Mitigation and Adaptation Plans (PMACC) in Peru

With its low coastal areas, arid and semi-arid areas, exposure to natural disasters, drought and desertification as well as highly polluted urban areas and fragile ecosystems, Peru's population and ecosystems are highly vulnerable to climate risks. Almost two-thirds (62%) of the country's population lives in the Pacific watershed, with only 2.2% of total water availablity. In this context, many utilities still struggle to deliver basic and equitable water and sanitation services. Growing urbanisation and a lack of wastewater treatment coverage both lead to an increasing water demand and pollution of water bodies. The expected impacts of climate change and variability might further worsen these existing challenges and add new ones. These climate risks will increasingly require proactive planning and implementation for delivering sustainable water and sanitation services.

Through a web-based tool for developing Climate Change Mitigation and Adaptation Plans (PMACC; Planes de Mitigación y Adaptación al Cambio Climático), water and wastewater utilities have received assistance in reporting climate risks and identifying effective short- and long-term adaptation measures, considering multiple benefits. This enables them to improve day-to-day operations and make resilient operational and investment decisions. The PMACC tool allows utilities to draw up climate change plans suitable to their different capacities, sizes and local operating contexts. The PMACC initiative has been implemented by GIZ, through the **Programme for Modernisation and Strengthening Water and Sanitation Sector (PROAGUA II)** on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ).

This planning approach has enabled water utilities in Peru to start implementing adaptation measures, such as the water utility in Moquegua increasing its water metering from 36% to 90% (improving water demand management), reducing water losses from 46% to 31%, and thus reducing daily per-capita water production from 386 to 258 liters, becoming more resilient to longer-term climate change-related water shortages. In order to enhance urban water supply security, PROAGUA II focuses on boosting climate resilience and helps build capacities to protect water resources from domestic and industrial pollution, ensuring that technical and professional staff qualification meets the sector's demands and that climate change adaptation is mainstreamed into sectorial policy and planning. Thereby, it establish a functional monitoring system for SDG 6 and water-related Nationally Determined Contributions (NDCs).

6.3 Resilient water management

While climate change and other trends often increase water-related risks in frequency and intensity, specific incidents including water scarcity, flooding, and increased water variability have been known for centuries. Farmers, planners, engineers, and others have developed and applied approaches for dealing with these risks. What has changed are the additional impacts due to climate change, which are often difficult to anticipate, in particular at the regional level.

In the last decades, it has become apparent that the overexploitation and pollution of water resources poses a serious challenge to the health of communities and ecosystems worldwide. In addition, urbanisation and land-use change often entail the sealing of previously permeable soils and the extension of built infrastructure into natural floodplains. These challenges require modelling capacities in order to make sustainable long-term infrastructure decisions, and have evoked new concepts of water management among public and private actors, including by the international development community.

These concepts can help to increase climate resilience if they respond to the specific climate risk context in a region. In any case, it is important to assess specific climate vulnerabilities, projections and potential impacts of climate change, including affiliated uncertainties, and expose how the planned activities will contribute to increasing climate resilience. The following concepts respond in particular to climate change-induced water scarcity, but also involve co-benefits for sustainable development as a whole.

Water Demand Management

Drought and water scarcity increase in many regions due to climate change and variability, increasing water use, change in land cover and other issues. About two-thirds of the world population experience severe water scarcity during one month of the year or more (Mekonnen and Hoekstra, 2016). In many cases, the management or reduction of water demand can increase resilience to climate change-induced water scarcity and provide a sustainable alternative to increasing water supply, in particular if sources are already used beyond safeyield.

Water pricing can contribute to reducing water demand without threatening safe water supply of adequate quality for vulnerable ecosystems and communities in compliance with the human rights to water and sanitation. For example, this can be achieved through charging higher tariffs for large commercial customers during dry months, while keeping an affordable price for the amount of water which is necessary for adequate living. Activities to encourage efficient water use also include non-pricing approaches, such as the installation of water meters or awareness campaigns and education, including on household water-saving behaviours and devices (Tortajada et al., 2019). The use of water-efficient and drought-resistant crops can decrease water demand for agricultural irrigation, so that saved water can be used for other purposes.

Water loss reduction

It is estimated that a large share of the water pumped in supply networks does not reach customers or is not billed. For instance, Mexican cities have reported water losses of more than 40% (OECD, 2016). Hence, the detection and reduction of losses from water networks, both administrative and physical, can substantially help to improve water security. As for the installation and rehabilitation of networks, it helps to increase climate resilience specifically in light of increasing water scarcity.

➔ ***The reduction of water losses can help to increase resilience to climate change- induced water scarcity.***

Physical water losses through leakage e.g. in pipes and storage systems can be reduced through repair. Unauthorised or unbilled water use, for instance through government agencies exempt from water billing, requires political support and must consider the needs of poor communities. The reduction of water losses results in less water that needs to be pumped, also saving electricity costs and, depending on the energy used, reducing GHG emissions.

Good practice example

Peru I: Implementing Resilient Water Management

Water loss reduction in coastal cities: Peru is particularly vulnerable to the impacts of climate change. Parts of the coastal dry areas are prone to drought and desertification. Natural water storage in glaciers in the Peruvian Andes, which has contributed to water security also in coastal areas, has started to disappear. Water scarcity threatens the economic development in those areas, which at the same time must also deal with population growth and increasing water demand.

Water suppliers in the coastal cities of Tacna and Chimbote face the challenge of meeting growing water needs. Due to deficient water networks and missing water meters, the utilities are neither able to quickly detect and fix leakage nor to measure individual water use and to reduce the excessive use of water through economic incentives. As a result, a large part of the population in both cities often gets water supply for only a few hours per day. On behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ), the German development bank KfW supports water utilities in Tacna and Chimbote in facilitating a sustainable and reliable water supply. The focus of the activities is the avoidance of water losses, for instance through network improvement and provision of equipment and material. The activities also include support for improving data and information on the network and water use. The network is divided into sectors in order to locate, analyse and reduce water losses. The installation of water meters at house level enables customers to monitor their own water consumption and reduce the respective costs. The programme also includes accompanying awareness campaigns. The initiative aims at enhancing climate resilience through increasing the continuity of water supply by at least two hours per day and contributing to the sustainable water supply in Tacna and Chimbote.

Peru II: How an agriculture company contributes to improving Peru's climate resilience

Virú Group ("Virú") is one of the three biggest agricultural exporters in Peru. In addition to its own cultivation, extending over 8,000 ha of farmland, Virú buys fruits and vegetables from smallholders. Its products are processed at three processing plants and distributed worldwide. It includes asparagus, artichokes, avocados, peppers, mangoes and heart of palms, as well as value-added products, such as pestos, bruschettas, and ready-to-eat meals. Its main customers are supermarket chains, including REWE, Carrefour, EDEKA and local traders.

The German development financier DEG supports expansion plans with long-term loans and assisted Virú as part of its Business Support Services (BSS) in implementing a state-of-the-art wastewater treatment plant, which enables the reuse of water and reduces the water footprint of the company. To ensure the sustainability of the water supply, Virú installed remote-controlled computer-based groundwater-level monitoring tools in all wells to track future trends in groundwater availability. The general water footprint is low, as modern drip irrigation systems are used for all production sites.

Recent studies on the relation between extreme weather events (El Niño) and the financial performance of Peruvian agricultural companies showed that the financial impact of El Niño was successfully mitigated in companies with a best-practice water management and emergency-response infrastructure, such as storage reservoirs providing irrigation water for at least seven days.

Network extension and rehabilitation

Despite the targets of the Sustainable Development Goal on Clean Water and Sanitation (SDG 6) to reach universal access by 2030, it is estimated that more than 2 billion people still lack access to safe drinking water. More than 800 million lack access even to basic water services. About 4.5 billion have no access to safe sanitation, more than half of which lack basic sanitation (UN, 2018). The lack of access to safe drinking water can significantly increase vulnerability to climate change-induced water scarcity, since communities without access often depend on water sources with significant variability in availability and quality. Availability and pricing, in turn, might be directly affected by the impacts of climate change.

Depending on the specific vulnerability context, the extension and rehabilitation of water network infrastructure can increase climate resilience and improve household income, access to education, food security and health. The necessary funding is usually provided by governments, partly assisted by the international donor community. The proper maintenance of existing infrastructure reduces the risk of deterioration and the need for costly rehabilitation efforts.

It is important to consider future climate impact scenarios during the planning and design phase.

Reuse of treated wastewater

Resilience to increasing water scarcity can also be improved through the reuse of treated wastewater as an alternative resource. Reuse for agricultural irrigation has been practiced for decades, in particular in water-scarce areas, for instance in Spain (Jódar-Abellán et al., 2019). Treated wastewater of adequate quality can also be used to recharge groundwater or surface water resources or for industrial purposes, for instance as cooling water. The direct reuse as drinking water, including through blending with other sources, is only practiced in a few cases, for instance in Singapore (Tortajada and Nambiar, 2019).

➔ ***Increasing coverage of wastewater treatment comes with opportunities for climate resilience and GHG mitigation.***

It is estimated that still over 80% of the world's wastewater, including more than 95% in some least developed countries, is discharged into the environment without any treatment, threatening marine and freshwater ecosystems, communities and contributing to GHG emissions (WWAP, 2017). As emerging and developing economies increase their coverage of wastewater treatment, the opportunity to use treated effluent or to store it as a substitute for scarce surface or groundwater is arising.

Treated wastewater can be used as a cost- and energy-efficient alternative water source for irrigation, especially compared to costly alternatives, such as the development and operation of long-distance transfer systems. Enabling conditions for wastewater reuse include an adequate institutional and regulatory framework and setting quality standards and norms for different use purposes. Potential users and their perspectives, including potential cultural taboos, must be involved in the decision-making process from the beginning. In addition, it should be noted that the reuse of treated wastewater might involve environmental and health risks, which can be contained by proper treatment and an adequate institutional and regulatory framework.

Desalination

In the case of water scarcity, increased by the impacts of climate change and variability, the generation of water through desalination processes can be a suitable alternative for improving climate resilience. Water-scarce coastal areas might consider desalination of seawater as one factor contributing to improved water security. Brackish water, for instance from aquifers, can provide an alternative source in dry areas, including in regions which are far from the coast and might otherwise consider using water which is transferred from long distances. Technologies for the desalination of saltwater and brackish water, e.g. through reverse osmosis, have become considerably cheaper and more energy-efficient in recent decades (Ghaffour et al., 2013). Due to the lower salt content, the desalination of brackish water requires less energy, and water quality is often better compared to seawater, making treatment processes less demanding.

The separation of salt generates brine as a byproduct, which has a very high salt concentration. If brine is not disposed of in an environmentally sustainable way, it can significantly threaten the health of ecosystems. Therefore, the challenge of sustainable disposal of brine needs to be addressed in the planning, design and operation phases of desalination activities. Brine can be diluted in seawater, for example through diffusors in accordance with the specific environmental and geographic conditions (Voutchkov, 2011). In landlocked areas, if conditions permit, approaches might include the sustainable disposal in evaporation ponds and natural sinks and injections in saltwater aquifers. It is important to mention that every case of desalination requires a thorough assessment of the social, environmental, marine, geographic and geological conditions, with the objective of minimising negative impacts through brine.

Even though desalination has become more efficient, it still requires a considerable amount of energy, for example for generating the necessary pressure in the reverse osmosis process. The use of fossil fuels for the necessary electricity would increase the emission of CO_2. Therefore, it is advised to assess the potential for increasing the share of renewable energy in the country's energy mix and to optimise energy efficiency when engaging in or expanding desalination practices. The respective infrastructure does not necessarily need to be built physically next to the desalination facilities for direct supply. Desalination requires continuous energy supply and would thus need a solution for energy storage. Instead, renewable energy might feed into the general electricity grid, which could also be connected to the desalination infrastructure. Only decentral desalination facilities without access to energy will need a specific new source of energy.

Resilient Rainwater Management

Changes in seasonal and geographic rainfall variability and intensity, as well as gradual trends in the total yearly amount of rain, are among the most direct impacts of climate change (*see Chapters 4 and 5*). Through an optimised rainwater management system, threats can be reduced and even turned into opportunities if rainwater is used as a resource.
For example, rain can be collected and used for groundwater recharge. Main goals of climate-resilient rainwater management include the prevention of flood damage, protection of water resources and optimisation of water use.

In cities, support for water retention areas can be combined with the creation of public parks, which are deliberately flooded in case of heavy rains. Surfaces in cities are often sealed, preventing the natural runoff of water. Permeable surfaces instead allow for water infiltration, improve natural drainage and can also have a cooling effect. Rainwater collection, diversion and storage can provide an additional source of water, especially in areas which are threatened by water scarcity. The specific elements of rainwater management depend on the location as well as the current and future climate, social and geographic features (Palazzo, 2019).

Resilient Sanitation Systems

While water is projected to be the main channel through which the impacts of climate change will be transmitted, the impacts on sanitation systems cannot be neglected. Extreme weather events such as drought, flooding, or storm surges, as well as sea level rise, put sanitation systems at risk. Yet, sanitation has received little attention in the discussion and research on the impacts of climate change. Information on what resilience means for different sanitation systems and how climate change might affect the way we manage sanitation services is sparse.

UNESCO and UN-Water (2020) emphasise that climate change is likely to slow down or undermine the achievements related to access to safely managed water and sanitation, if the design and management of systems is not made climate-resilient. Even small losses of sanitation coverage due to impacts of climate change can have disproportionate effects on public health. For instance, a whole community can be affected by contamination even though only a few latrines were flooded.

An increased occurrence of floods and heavy rainfall can be a challenge for sanitation systems, especially in cities. Flooded pit latrines or septic tanks can cause uncontrolled discharge of untreated faeces and wastewater, thus posing a public health risk. Sewage treatment plants can also be damaged due to extreme weather events. Periods of drought pose challenges to water-based sanitation systems. Water shortages can impair the functionality of sewer systems and lead to their accelerated corrosion. In addition, the concentration of pollutants in wastewater can become higher and thus exceed the capacity of receiving waters. The rise in sea level might affect sewage treatment plants, which are increasingly located in coastal, low-lying areas (of cities). Floods, storm surges and saltwater intrusion can significantly threaten the functioning of wastewater treatment plants. Increasing intensity and frequency of storms may damage or even destroy sanitary infrastructure (latrines, sewers, sewage treatment plants). Accompanying interruptions in the power supply also threaten the operation of grid-connected sanitary systems.

Sustainable and climate-resilient sanitation systems are therefore necessary in protecting public health. They can also make a significant contribution to urban resilience, as they can be a source of water, energy and nutrients. Recent research suggests applying several principles to increase the resilience of urban sanitation systems including: optimised and robust hardware to sustain shocks; flexible options and diversified risks; adaptive management to withstand disturbances; raised awareness and knowledge to minimise damage; consideration of complex system dynamics; and attention to the distributional effects on equity. While the resilience of the hardware is important, the flexibility and adaptability of operation and management of services is equally relevant, in order to address the uncertainty of climate change impacts (ISF-UTS and SNV, 2019).

6.4 Nature-based Solutions and Ecosystem-based Adaptation

As shown in *Chapters 4 and 5*, even small changes in climate can significantly change hydrological patterns at the river-basin and local scale, for instance through more intense and more frequent floods and droughts. Extreme weather phenomena severely affect ecosystems and have potentially devastating socio-economic impacts (McKinsey, 2020).

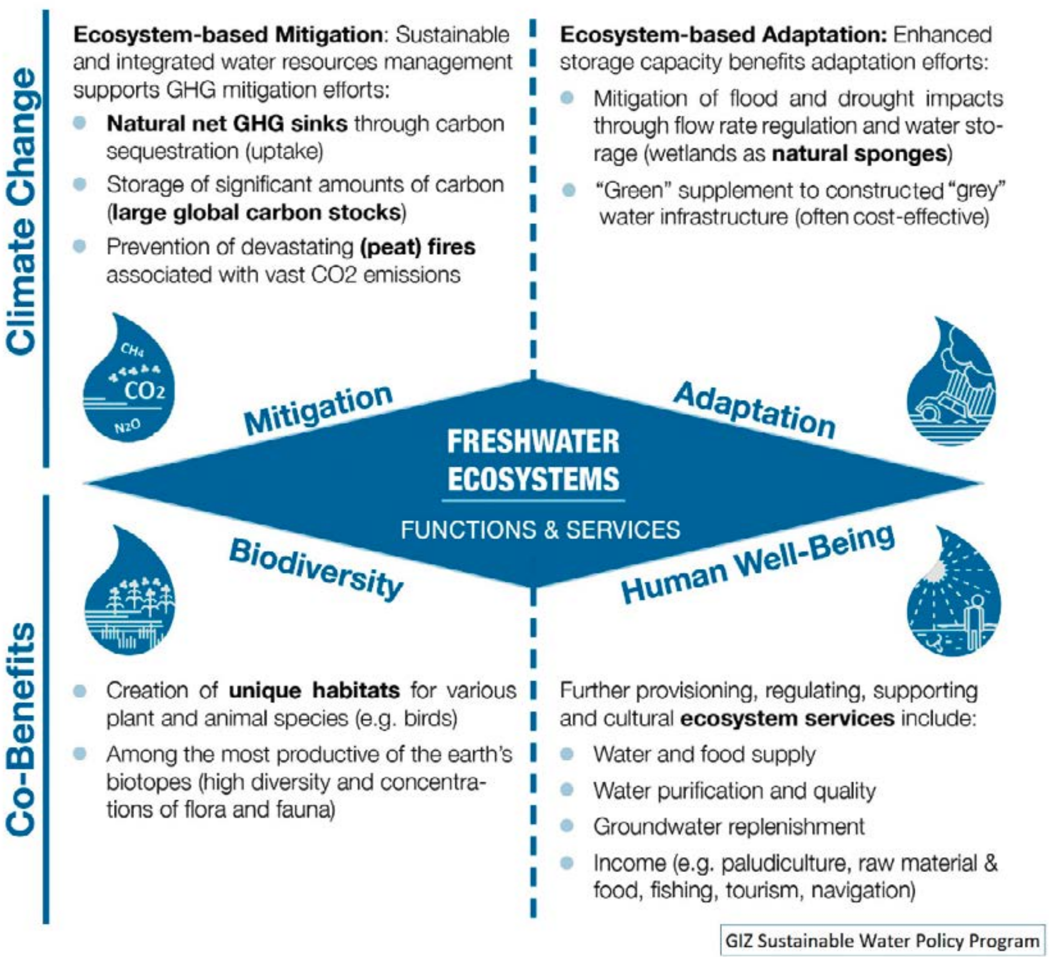
Nevertheless, if managed appropriately, ecosystems can absorb parts of the impacts of climate variability and change. For instance, forests and wetlands can catch a share of floodwater and might derive part of that water to recharge aquifers. In addition, ecosystems can also contribute to the mitigation of GHG (*see Chapter 7*), while safeguarding biodiversity and fostering human well-being (e.g. economic activities, livelihoods, etc.).

➔ ***Ecosystems can absorb part of the impacts of climate variability and change.***

Ecosystem services are goods and services provided by healthy ecosystems (*see definition box below*). Essential water-related ecosystem services include coastal flood and drought protection by mitigating adverse effects of weather variability and extremes. Other services comprise water purification as well as the reduction of erosion and sedimentation. *Figure 32 below* provides an overview of potential functions and services provided by freshwater ecosystems with a focus on wetlands. However, most of the described benefits are also applicable to lakes, rivers or spring ecosystems. The figure displays that the benefits for climate action provided by healthy water-related ecosystems usually come along with several co-benefits in different socio-economic and environmental spheres.

Ecosystems can play an essential role in promoting robust, but flexible adaptation solutions. The corresponding climate activities often also aim at protecting, sustainably managing or restoring ecosystems in order to effectively address societal challenges. Such activities can be grouped under the concept of **Nature-based Solutions (NbS)**, as described in more detail below. A strategy that builds on NbS in order to particularly address climate change impacts is called an **Ecosystem-based Adaptation (EbA)** approach (*see definition box below*).

Figure 32: Freshwater ecosystems' functions and services for climate change mitigation and adaptation, and related co-benefits. Source: GIZ



Definition of terms

Nature-based Solutions, Ecosystem Services, Ecosystem-based Adaptation, Ecosystem-based Mitigation

The term **Nature-based Solutions (NbS)** emerged around 2002 (Cohen-Shacham et al., 2016). IUCN defines NbS as "actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits". The defining feature of an NbS is, therefore, not whether an ecosystem used is 'natural', but whether natural processes are being proactively managed to achieve set objectives (compare Cohen-Shacham et al., 2016; Nesshöver, 2017; UNESCO WWAP, WWDR, 2018). It can be used as an umbrella concept that covers a range of approaches, including ecosystem-based approaches and green infrastructure.

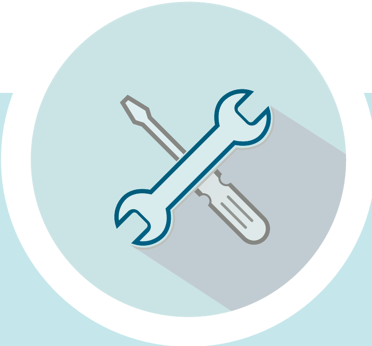
Ecosystem Services are goods and services provided by healthy ecosystems, including medicinal plants, clean water and air, and protection from extreme natural events (IUCN, 2018).

Ecosystem-based Adaptation (EbA) is an issue-specific Nature-based Solution for addressing climate change impact. The term EbA was coined in 2008 and defined in 2009. The definition of EbA used in the Convention on Biological Diversity (CBD) is now the most commonly accepted (Friends of Ecosystem-based Adaptation (FEBA) 2017):
"Ecosystem-based Adaptation is the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change."

Ecosystem-based Mitigation (EbM) is an issue-specific Nature-based Solution that uses "ecosystems for their carbon storage and sequestration services to aid climate change mitigation" (Doswald and Osti, 2011). Emissions reductions are achieved through creation, restoration and management of healthy ecosystems (e.g. forest restoration, wet-/peatland conservation).

EbA approaches have gained importance under the UNFCCC Paris Agreement (e.g. in Nationally Determined Contributions (NDCs), climate finance, national policies and budgeting) (FEBA, 2017). Furthermore, ecosystems' potential in terms of climate change mitigation can be included in overall mitigation strategies as approaches (*see Chapter 7*). However, in order to avoid inadequately "re-packaging" business-as-usual conservation or development activities as EbA activities, quality standards have evolved to guarantee appropriateness and coherence. Regarding the water sector, these criteria and standards can help to design and/or implement EbA measures in order to clearly demonstrate the climate change adaptation effects of a respective water management action. Furthermore, there are several other guidelines and tools for the resilient design, effective implementation and impact assessments of EbA approaches in addition to the criteria defined by FEBA (*see box on the next page*).

Tools



Selected guidebooks for resilient design, effective implementation and impact assessment of Ecosystem-based Adaptation

Several guidelines, guidebooks and sourcebooks have recently been published with support by several donors, including the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) and co-produced by GIZ. Some of the most recent ones include:

Voluntary guidelines for the design and effective implementation of ecosystem-based approaches to climate change adaptation and disaster risk reduction and supplementary information (2019) (English) (Secretariat of the Convention on Biological Diversity, 2019).

Guidebook for Monitoring and Evaluating Ecosystem-based Adaptation Interventions (2020) – Practical guidebook for planners and practitioners that describes key considerations and components for each step of Monitoring and Evaluation (MandE) of EbA projects and points to additional tools and methodologies that can be used under specific circumstances (English) (GIZ, UNEP-WCMC and FEBA, 2020).

Climate Risk Assessment for EbA (2018) – A guidebook for planners and practitioners providing a standardised approach to assessing risks within social-ecological systems based on two application examples (river basin and coastal zone management) (English/Spanish) (GIZ, EURAC and UNU-EHS, 2018).

Valuing the Benefits, Costs and Impacts of EbA (2017) – A sourcebook of methods for decision-making and valuation of benefits, costs and impacts (English/Spanish) (Emerton, 2017).

Making Ecosystem-based Adaptation Effective: A Framework for Defining Qualification Criteria and Quality Standards (2017) – A practical assessment framework for designing, implementing and monitoring EbA measures that encourages practitioners and decision-makers to use them. (English) (FEBA, 2017).

Enabling Ecosystem-based Adaptation (EbA) through Integrated Water Resources Management (IWRM) (2020, forthcoming) – Based on case studies, this report for planners and practitioners showcases the potential of IWRM processes as an entry point for a wider-scale landscape approach to EbA planning and implementation (GIZ, 2020).

Nature-based Solutions for flood risk management

As shown in *Chapter 5*, the risk of more severe flooding events is projected to increase, for example in the Upper Niger, the Blue Nile and the Ganges. Here, NbS – specifically EbA – offer great potential for robust and flexible flood risk management strategies. Decision-makers should agree on an adequate combination of infrastructure-based (grey) and/or nature-based (green) adaptation options on the basis of best available information. For example, nature-based flood retention measures can store stormwater, and thus complement and reduce the need for grey infrastructure designed for urban drainage systems. River floodplains can store flood water and thereby reduce the need to build embankments (Browder et al., 2019). Climate resilient flood risk management strategies also hold great potential for complementing overall disaster risk reduction efforts (*see box on Ganges Case Study on page 97*).

Dadson et al. (2017) grouped common nature-based measures in flood risk management into three categories:

1. **Water retention in the landscape through management of infiltration and overland flow:** Increasing water retention in the landscape can be done through land-use changes (e.g. grassland conversions, wetland/peatland restoration), other forms of agricultural practices (cover crops, crop rotation) and livestock practices (restriction of grazing season), among others. Further measures include managing field drainage and creating buffer zones on farmland, such as shelter belts.
2. **Managing the hydrological connectivity and the conveyance of water in the landscape:** This can be done by the management of farmland (hillslopes, ponds and ditches), channel maintenance, modifications to drainage regimes and the placement of farm structures, such as culverts.
3. **Making space for water storage** (*see Chapter 6.5*)**:** Water can be stored in aquifers, reservoirs as well as in wetlands. Another measure is to restore floodplains through reconnecting rivers and setting back embankments, for example. Restoring river profiles and maintenance can increase space for water, reducing the need for space in other areas in case of flooding.

Experience has shown that NbS are often most effective when green infrastructure is combined with grey infrastructure approaches. Such a combination can provide cost-effective adaptation solutions with a significant risk reduction potential. The predominant type of land use, along with existing social, ecological and hydrological settings, mostly determines which combination of nature-based and infrastructure-based options performs most effectively.

Good practice example

Implementing EbA within watershed management to manage extremes in South Africa

Droughts in South Africa are becoming increasingly common. In KwaZulu-Natal the "uMngeni Ecological Infrastructure" project aims at integrated watershed planning and management. The goal is to improve the resilience of water services to climate change at a watershed scale. The "Ecological Infrastructure Partnership" is a collaboration of public and private actors who share expertise and resources to protect and enhance the state of ecological infrastructure in the uMngeni catchment. The initiative has 23 signatories and is part of the "Strategic Infrastructure Investment Project 19". The project follows the principles of EbA by using the ability of ecosystems to provide services to downstream communities in a resilient manner. It seeks to enhance governance and regulatory capacity at a catchment scale while implementing restoration measures in selected sites, thus leading to improved water services to downstream communities. The socio-economic co-benefits include improved livestock production, an increase in employment in rural areas, and the long-term protection of species-rich endemic grassland ecosystems. The project was funded by the Critical Ecosystem Partnership Fund and implemented by Wildlands Conservation Trust.
Source: GIZ, 2019.

6.5 Flexible water storage

As shown in *Chapter 5*, many river basins are expected to experience an increase in the probability and/or severity of hydrological extremes and the variability of the local climate. Water storage systems are essential for dealing with seasonal and annual water variability and can also serve as a buffer against extremes, providing answers to multiple impacts of climate change and variability through the following functions:

- Store part of the excess water during extreme precipitation and flooding;
- Gradually release stored water in times of drought;
- Balance increasingly uncertain water variability;
- Replace natural storage systems threatened by climate change, such as glaciers.

In this context, it should be noted that in some regions, such as the Andes and the Himalayas, water storage in glaciers is an essential element of the water cycle in the respective basins, including the Ganges basin (*see Chapter 5.2*) and the Upper Amazon basin (*see Chapter 5.3*).

➔ ***Water storage can provide answers to multiple impacts of climate change and variability.***

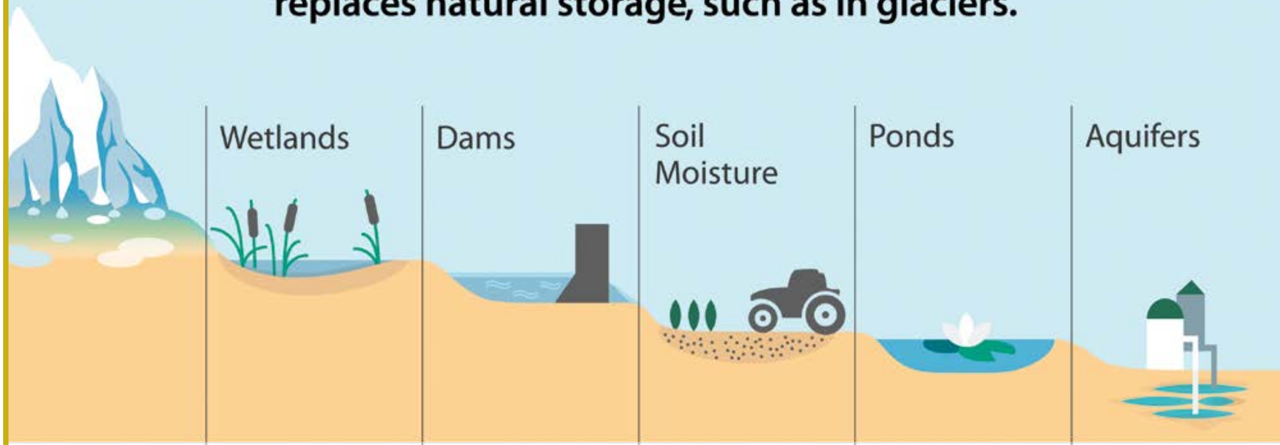
In the face of climate change, natural storage system depletion, and increased water demand, the ability to accommodate varying levels of precipitation and hydrological flows is essential. To this end, more storage systems are needed, and these should be flexibly designed and managed.

In light of increasing uncertainty about future climate conditions, relying on grey infrastructure alone will not be enough. Rethinking how green NbS can best be combined with infrastructure-based grey measures is necessary to manage climate risks, while safeguarding freshwater ecosystems. There are various nature-based approaches to increasing storage capacity and thereby fostering adaptation efforts, including through the conservation of wetlands, afforestation of catchment areas, managed groundwater recharge, and improved soil moisture retention. At the same time, these measures to increase storage capacity often provide co-benefits, for instance in terms of biodiversity protection, GHG mitigation, and soil erosion control.

The **Water Storage Continuum Concept** (McCartney and Smakhtin, 2010) suggests that storage planning at river basin and regional scales should consider a portfolio of surface and sub-surface storage options, including reservoirs, wetlands, soil moisture, ponds and aquifers, with the objective of achieving the best environmental and economic outcomes in the face of the case-specific vulnerability and climate change impact scenarios. Each of these storage options has its own strengths and weaknesses, which often further depend on the biophysical and social contexts in which they are implemented. Climate change also affects different storage types in different ways: under some climate scenarios, some types might fail, while others may continue to function. *Figure 33* provides an overview of different water storage systems, their potential for increased climate resilience and related co-benefits, as well as potential disadvantages. In light of increasing climate variability, and uncertainty of future climate and socio-economic scenarios, McCartney and Smakhtin (2010) recommend combining different types of storage in a system. This will improve the overall storage system's ability to perform under various climate scenarios, as well as create flexibility in adapting storage management to changing conditions. McCartney et al. (2013) provide a tool for a rapid (first-cut) evaluation of the effectiveness of different water storage options under existing and possible future climate conditions, which is based on a set of biophysical and demographic indicators.

On a related note, also fossil and deep-lying groundwater resources can be an important source of high-quality drinking water in several regions, such as in dryland regions in Africa (e.g. in the Sahara and Kalahari regions). As such, they may serve as a temporary solution for drinking water supply and may account for shortages in surface water availability during drought events. Yet, it must be emphasised that, especially in dryland regions with little or no groundwater recharge, fossil groundwater resources are often not renewable and are therefore not a long-term solution for water supply.

Resilient water storage buffers the impacts of climate change and replaces natural storage, such as in glaciers.



	Wetlands	Dams	Soil Moisture	Ponds	Aquifers
Flood mitigation potential	Capture and slowly release floodwaters Detain floodwater pollutants	Rapid uptake and release High storage capacity	Reduce run-off and increase retention	Cost-effective and solution but limited capacity	High storage capacity but slow uptake through infiltration
Drought mitigation potential	Maintain river flows during dry periods Inundated areas recharge aquifers	Long-term predictable storage Controllable release	Extends period of water availability	Decentral low-cost solution but limited reliability	Long-term storage without evaporation losses
Other benefits	Ecosystem-based Mitigation: Carbon sink & storage Support livelihoods and high biodiver-sity Natural water treat-ment	Renewable energy generation	Support livelihoods (rainfed agricul-ture)	Support livelihoods (aquaculture)	Improves water quality Artificial recharge mitigates land submergence and counteracts saltwater intrusion
Disadvan-tages	Potentially produce CH4 emissions	High evaporation losses Potentially high social and ecological costs Potentially produce CH4 emissions	Use limited to plant growth	High vulnerability to pollution	Potentially high energy consumption for infiltration and pumping

Figure 33: The potential of different water storage systems for increased climate resilience (own compilation based on McCartney and Smakhtin, 2010)

Managed Aquifer Recharge as part of flexible storage concepts

Sub-surface storage options include techniques that intentionally enhance natural groundwater recharge by building infrastructure and/or modifying the landscape, collectively known as **Managed Aquifer Recharge (MAR)**. MAR, which is also applied in combination with surface water storage, is one storage approach that holds major potential for alleviating adverse impacts of both floods and droughts in a particular basin.

MAR techniques range from sophisticated infiltration wells to the relatively simple measure of decentralised stormwater infiltration. MAR has the potential to serve various purposes, including maximising water storage, replenishing depleting aquifers, improving water quality, preventing saltwater intrusion into groundwater in coastal areas, improving soil quality and providing ecological benefits, such as safeguarding groundwater-dependent plant communities or enhanced downstream river flows. In any case, a sound knowledge of the soil, aquifer and water conditions is a prerequisite for effective use of MAR.

Moreover, risks of groundwater pollution must be considered, e.g. when infiltrating stormwater. For instance, infiltration of water can mobilise potentially hazardous substances in the sub-surface. The implementation of MAR measures should, therefore, follow a careful approach, involving a thorough desk study assessment and feasibility study, as well as a first pilot MAR activity with adequate testing and monitoring. If successful, a more comprehensive MAR system with continuous monitoring of quantity and quality could be installed.

6.6 Transboundary Resilience Management

Administrative boundaries do not stop the natural flow and extension of rivers, lakes and aquifers. 310 rivers and lakes, covering 47% of the Earth's land surface (McCracken and Wolf, 2019), as well as numerous groundwater aquifers, cover two or more sovereign states. As outlined in *Chapter 5*, the climate-related challenges facing many transboundary river basins are considerable. Some countries, such as Egypt, depend almost entirely on water coming from neighbouring states. In the case of shared water resources, water management activities in one country might affect the quantity and quality of water resources in neighbouring countries.

In order to improve water-related cooperation among riparian countries, **Transboundary Water Management (TWM)** activities have been agreed upon and supported by the international community in recent decades. Many transboundary river basins, such as the Mekong, Nile and Niger basins, have established their own transboundary River Basin Organizations (RBOs). International conventions on TWM include the 1997 UN Water Convention and the 1992 Convention on Transboundary Watercourses of the UN Economic Commission for Europe (UNECE). Today, TWM has become an internationally recognised and renown concept for improving regional cooperation and preventing conflicts through water cooperation.

To address the climate change-related challenges outlined in *Chapters 4 and 5* of this report (e.g. the risk of projected increases in flooding in the Niger, Blue Nile, and Ganges basins), transboundary water cooperation should account for climate change and related uncertainties. By working together, actors at the transboundary, national, and local level can harness the potential of water governance and climate policy approaches for both climate change adaptation and mitigation, as well as water security. In doing so, they can further build on well-established examples of transboundary water cooperation and take cooperation to another level: **Transboundary Resilience Management (TRM).**

➔ ***Following a TRM approach, decision-makers can create synergies and co-benefits in river basins by integrating water and climate interventions more closely.***

The aim of TRM is to combine key elements of climate resilience with transboundary cooperation mechanisms in order to support implementation of collaborative climate action. Elements of resilience management include a mechanism for integrated climate risk and vulnerability assessments, a strategy and planning process and realistic financing options. Such a management approach may even be expanded to complement national climate plans and strategies through transboundary planning documents, including both mitigation and adaptation aspects.

While the strength, mandate and scope of transboundary RBOs varies considerably from one basin to another, they regularly have established governance functions that are critical for resilience management, including data collection and storage, knowledge generation, processes for participation of stakeholders from different levels and sectors, and for coordination of various interests. In addition, they often have established mechanisms for strategic and investment planning and dispute settlement. In order to be resilient,

Good practice example

Basin Ganges – Managed Aquifer Recharge (MAR) for flood mitigation and dry-season water supply

The Ganges is the world's most populous river basin. More than 650 million people rely on its waters and ecosystem services. Over recent decades, the Ganges has become one of the most polluted large rivers and, especially during the last few years, some lower reaches of the river have had unprecedented low water levels during the pre-monsoon season. This has caused high damage to surface drinking water supply, power generation units, irrigation systems and navigation. These low water levels are mainly caused by the overexploitation of groundwater (Mukherjee et al., 2018). Climate change is aggravating this situation, which is already perceived as a water crisis. Precipitation, and hence river flows might increase in the future, but climate change may also cause more extreme weather events (see Chapter 5.2).

A comprehensive basin-wide assessment by the World Bank (2014) found that the current capacity in the basin to manage floods and droughts is likely to be inadequate. Furthermore, while it plays a key role for adaptation and disaster risk management, large-scale infrastructure, such as dams alone, will not be enough to avert the worst of climate impacts on local communities in the basin's highly variable monsoon-driven climate. The study recommends transitioning from mere flood control to flood management. Infrastructure-based interventions need to be complemented by nature-based interventions with a more pronounced focus on regional forecasting and/or warning systems, drainage and "soft" responses, such as disaster preparedness or flood insurance.

When it comes to tackling more frequent extreme weather events and aggravating water scarcity in the future, underground water storage solutions are emerging as a potential adaptation solution for the basin. Underground Taming of Floods for Irrigation (UTFI) is a MAR-based approach to facilitate aquifer recharge and store wet-season high flows in upstream areas, in order to mitigate the risk of flooding further downstream at basin scale.

The groundwater recharge structures installed in upstream areas both offer flood protection and form water reserves for the dry season or prolonged droughts. UTFI is still at an early stage of development. The International Water Management Institute (IWMI) has investigated the potential of the concept (Pavelic et al., 2015), estimating that 68% of the area in the basin closest to the river is highly or very highly suitable for deploying the concept. The project also established a pilot in Western Uttar Pradesh, which serves both as a scientific experiment and practical demonstration. UTFI has also been applied in the Chao Phraya River Basin in Thailand (WWAP/UN-Water, 2018). While the potential to deploy UTFI across the basin is theoretically large, further research is needed to validate its technological feasibility and economic viability.

the institutional and other governance frameworks for transboundary cooperation themselves also need to provide for flexibility in adapting policies, strategies and institutional structures to changing conditions. This requires regular review processes that allow for learning and strategies that adapt accordingly. Moreover, the scope of cooperation might be extended beyond water to include other critical sectors, such as energy and agriculture. As in all climate-related initiatives, it is essential to gain ownership by the member countries' focal points to the UNFCCC, in most cases the environment ministries, but also planning and finance ministries.

Despite the water sector's long-standing experience in fostering transboundary cooperation, it is often a challenging process, as riparian states might have differing investment priorities and adaptation goals. It should be noted that transboundary water cooperation arrangements provide suitable mechanisms for increasing regional (climate) resilience. Proactive countries might also start TRM with one or more engaged neighbours, if there is no existing transboundary institutional structure. In turn, climate adaptation can also be an entry point for improved transboundary cooperation on topics that are potentially sensitive. Joint climate adaptation action on a transboundary basin level can help to establish a way of cooperation that is focused on beneficial aspects of collaboration (e.g. creating win-win scenarios for improving climate resilience) rather than on potentially controversial ones.

Transboundary Climate Risk and Vulnerability Assessments

Many countries have already conducted climate risk and vulnerability assessments at the national level. However, making use of transboundary climate risk and vulnerability assessments can complement a national perspective by identifying and planning joint adaptation activities.
The process of preparing a climate risk and vulnerability assessment is also an opportunity to raise awareness and build trust between the parties involved, as is data and information-sharing in general. In many basins, local or national efforts to adapt to present and future climate conditions are already underway. The joint assessments can be an effective means to draw attention to such efforts, evaluate them, and, if deemed successful, promote them in other parts of the basin. If conducted in a systematic, comprehensive, and inclusive fashion, such assessments can lay a solid, explicit foundation to proceed with joint adaptation planning and implementation in transboundary river basins (Fritzsche et al., 2014; UNECE and INBO, 2015).

Examples of vulnerability assessments for international river basins already exist: For instance, in 2013, the UN Environment Programme (UNEP) published a vulnerability assessment report on the Nile River Basin. The report, which was prepared in cooperation with the Nile Basin Initiative (NBI) and the Nile Basin states, makes use of satellite and other data to address questions surrounding the potential future impacts of climate change on the Nile water systems and the hotspot areas that are especially vulnerable to these changes. It also discusses possible action to manage or avert negative effects of climate change (UNEP, 2013b). Climate risk assessments have also been prepared for, among others, some of the case study basins of this report (*see Chapter 5*).

Good practice example

Climate risk assessment to inform adaption responses for water resources development in the Niger Basin

The Niger Basin Climate Risk Assessment (NBA and WB, 2014) has played an important role in building knowledge on how to enhance the resilience of water resources against climate change and variability in the Niger Basin. Undertaken as a joint initiative by the Niger Basin Authority (NBA) – the transboundary RBO – and the World Bank, its aim was to assess climate change risks for different water-using sectors, and particularly the Sustainable Development Action Plan (SDAP), which was adopted in 2008 by the Heads of State of the nine NBA member countries (Andersen et al., 2005).

The methodology of the Niger Basin Climate Risk Assessment follows a bottom-up, risk-based approach (see Chapter 6.2). As a first step, the study develops an understanding of the water resources system in the Niger Basin, planned SDAP infrastructure investments and how climate change will possibly affect them. The central question of the assessment was how future changes in precipitation would alter run-off patterns and eventually affect the performance of the SDAP infrastructure, focusing on the planned Fomi, Taoussa, and Kandadji dams and associated irrigation schemes.

As a second step, 38 climate projections derived from 15 GCMs were used to validate climate hazards and their probability of exceeding identified risk levels, and recommended relevant adaptation options in the Niger Basin. The assessment suggests that climate change impacts on runoff in the basin are moderate, mostly projecting runoff changes from -18% to +10% by 2050. According to the study, irrigated agriculture is relatively insensitive to these projected changes, if the existing Sélingué dam at the Sankarani tributary in Mali and the three planned dams mentioned above are fully replenished during the rainy season. SDAP, and in particular the planned Fomi dam in the Guinean highlands, are characterized as insurance for the protection of irrigated agriculture against the potential impacts of climate change.

However, crop water requirements might increase by 5% due to higher temperatures by 2050. Under the SDAP scenario, including the construction of the Fomi, Taoussa, and Kandadji dams, minimum river flows and associated ecosystems passing the Markala dam in the Middle Niger Basin could be severely hit by growing water abstraction due to warmer temperatures. The analysis reports a 50% probability that, once in five years, the ten-day average minimum flow at Markala dam will be less than $25m^3$ per second (the adopted minimum norm is $40m^3$). Improving irrigation efficiency would help to moderate water demand and increase climate resilience.

Since the overall sensitivity of the SDAP to the impacts of climate change is projected to be relatively low, the authors recommend focussing on managing freshwater variability in the short- to medium-term. As a co-benefit, this could also increase resilience to potentially increasing water variability. Water managers can contribute to increased resilience against climate variability and change with their long-standing experience in dealing with a climate that has been extremely variable in the Niger River Basin in recorded history, for instance through water harvesting, micro-water storage systems and ecosystem conservation.

Regional Adaptation Strategies and Planning

Transboundary approaches to adaptation strategies and plans could take different forms, ranging from regional harmonisation of adaptation plans to jointly implemented investments that are mutually beneficial, up to basin-wide adaptation plans (World Bank, 2017). Extending the strategy and planning efforts that take place at the national level (e.g. within the framework of developing NDCs and NAPs) to the bilateral or regional level could help to strengthen approaches enhancing transboundary resilience. However, in the absence of sufficient institutional and financial resources, expanding the scope of these planning processes to the regional level may overwhelm national actors' capacities.

If national actors fail to consider the cross-border consequences of adaptation interventions, climate change adaptation might strain inter-riparian relations, thereby increasing the risk of water and climate change-related conflict. This could occur, for example, if a water storage facility is constructed upstream in order to improve climate resilience without considering downstream effects, such as reduced water availability for human livelihoods and ecosystem needs (Tänzler et al., 2013).

In an international climate context, the LDC Expert Group (*see Chapter 8*), for instance, has highlighted potential ways in which regional cooperation can inform and aid the adaptation process (LEG, 2015). There are successful examples of regional cooperation, such as data collection when national capacities in this area are limited. Regional cooperation can create opportunities and synergies for an integrated planning insofar as national governments can profit from established regional expertise, data and information. Conversely, there are examples of national planning instruments that have already been used in the context of transboundary water management activities. One example is the Niger Basin Authority (*see box on Niger case study on page 63*), which used NAPs and National Adaptation Programmes of Action (NAPAs) to coordinate and prioritise planning for different adaptation activities.

Actors have requested appropriate climate finance support for river basin cooperation and specifically for RBOs (see Tänzler et al., 2013; Blumstein et al., 2016). Most recently, the World Bank analysed the current prospects of climate financing for transboundary water cooperation (World Bank, 2017). It considers transboundary RBOs to be in a unique position to ensure long-term planning and implementation of resilience-building projects (World Bank, 2017). The RBOs of Niger and Lake Chad have presented plans to encourage climate resilience investments and support the implementation of climate-related activities. In addition, at the Mekong and the Nile, RBOs have prepared strategies and project proposals to access climate finance and published transboundary adaptation. Meanwhile, some climate funding channels, such as the Adaptation Fund, have started to include transboundary activities into their portfolio.

Insights on Transboundary Resilience Management in select case study basins

RBOs that are active in the river basins introduced in *Chapter 5* or their superordinate basins have already implemented climate programmes at the basin level. Some have also conducted climate risk assessments with a varying level of detail and geographic scope. In addition, joint strategies on climate resilience have been prepared.

Nile Basin (including the Blue Nile)

With the founding of the Nile Basin Initiative in 1999, ten Nile Basin countries formed an intergovernmental partnership to institutionalise transboundary water cooperation. The basin-wide institution provides a forum for the basin states to consult each other and coordinate the sustainable management and development of the shared Nile Basin water and related resources. When it comes to addressing climate change impacts, the NBI has carried out various activities to strengthen TRM:

Climate Risk Assessment

The UNEP's Division of Early Warning and Assessment (DEWA) published a Vulnerability Assessment Report in 2013 (UNEP, 2013b). The assessment was produced in collaboration with the Nile Basin Initiative, the Nile Basin Partner States, the UNEP-DHI Centre for Water and Environment and the Global Water Partnership (GWP). One of the study's key recommendations was that policymakers should employ climate-compatible development strategies that promote economic growth, while reducing risks to the environment. In addition, the authors suggested focusing on the sustainable use of groundwater resources by investing in and building up local actors' capacity to gain a full understanding of the local and transboundary aquifers.

Joint Strategy, Planning and Coordination

There are several efforts that can be used and further developed to jointly address climate change in the basin. The NBI 10-Year Strategy for 2017-2027 chose climate change adaptation (improve basin resilience to climate change impacts) as one of its six goals.

Joint Programmes and Projects

There are already several programmes and project-related activities that can support the implementation of the strategy and strengthen transboundary resilience management. The GIZ is currently implementing a project on conserving biodiversity in the Nile Basin transboundary wetlands (2015-2020) commissioned by the German Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety (BMU) – this is additional to overall support of the NBI provided by GIZ, thanks to financing from the German Federal Ministry for Economic Cooperation and Development (BMZ). Meanwhile, UNDP is currently implementing a Global Environment Facility (GEF)-financed project to enhance joint management of surface and groundwater resources in selected transboundary aquifers in the Nile Basins, executed by NBI.

Ganges Basin

The Joint River Commission between India and Bangladesh was formed in 1972 to deal with potential disputes about sharing more than 50 transboundary rivers. The two countries have agreed to cooperate on the Ganges and signed a respective treaty in 1996. However, this treaty (even more so in a larger basin perspective, which includes China and Nepal) has no focus on climate change-related challenges yet. A prominent entry point for starting an assessment is "The Ganges Strategic Basin Assessment" prepared by the World Bank (World Bank, 2014) that seeks to facilitate regional cooperation in the sustainable use and management of the water resources of the Himalayan rivers. This basin assessment, however, has only a limited scope on climate change challenges and solutions.

Upper Amazon Basin

While the relevant authorities at the Upper Amazon do practice transboundary water cooperation, they do not take the institutionalised approach common to many other transboundary rivers. Nevertheless, several intergovernmental organisations play an important role in addressing climate change challenges in the region (USAID, 2018). For instance, there is the Latin American Technical Cooperation Network on National Parks, other Protected Areas and Wildlife (REDPARQUES), a network of public and private entities established in 1983 by the countries of Latin America. The REDPARQUES programme "Protected Areas, Natural Solutions against Climate Change", implemented jointly with the World Wide Fund for Nature (WWF), focuses specifically on how the protected areas of the Upper Amazon region in Colombia, Ecuador and Peru can help to build climate resilience. The programme is financed by the German Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety (BMU).

Another key player is the Amazon Cooperation Treaty Organization (ACTO), an international organisation that seeks to promote sustainable development in the Amazon basin. The member parties include Bolivia, Brazil, Colombia, Ecuador, Guyana, Peru, Suriname and Venezuela. The parties signed the treaty in 1978 and created ACTO in 1995 to strengthen its implementation. By 2010, ACTO had started to include climate change considerations into its Strategic Cooperation Agenda, according to USAID (2018). In cooperation with UNEP and supported by the GEF, the member countries executed the project "Integrated and Sustainable Management of Transboundary Water Resources in the Amazon River basin, considering Climate Variability and Change (2013-2018)".

Joint Strategy, Planning and Coordination and Joint Programmes and Projects

In 2018, ACTO published "The Strategic Action Program – Regional Strategy for Integrated Water Resources Management in the Amazon Basin" (ACTO, 2018). Among the overall 19 strategic actions outlined in the programme are a) the implementation of a Regional System to Monitor Water Quality in the Rivers of the Amazon Basin, b) the development of a Programme for the Protection and Use of Groundwater for Public Supply in the region, and c) the creation of Forecast and Warning Systems for Extreme Hydroclimatic Events (droughts and floods), as well as d) the establishment of an Integrated Regional Platform for Information on Water Resources in the Amazon Basin.

Niger Basin

The Niger Basin Authority (NBA) is an intergovernmental organisation aiming to foster co-operation in managing and developing the resources of the basin of the Niger River.

Climate Risk Assessment

As discussed above, the 2014 Climate Risk Assessment (NBA and WB, 2014) assessed the climate change impacts on a basin-wide action plan. The Niger Basin Sustainable Development Action Plan (SDAP), adopted in 2008 by the Heads of State and Government of the nine member countries of the NBA, is one of the major initiatives under the authority with a strong focus on managing several hydroelectric and agricultural dams built along the river.

Joint Strategy, Planning and Coordination and Joint Programmes and Projects

In 2018, the Green Climate Fund (GCF) board approved the Programme for integrated development and adaptation to climate change in the Niger Basin, a multinational programme involving the nine basin countries Benin, Burkina Faso, Cameroon, Chad, Côte d'Ivoire, Guinea, Mali, Niger and Nigeria. The program is co-financed by the African Development Bank (AfDB), the EU Commission's Africa Investment Facility, the GEF, the Forest Investment Fund (FIP) and the various national governments with a combined investment of almost USD 210 million, including loans, grants and in-kind finance. The main objective is to improve the resilience of populations and ecosystems in the Niger Basin through sustainable management of natural resources. The programme is executed jointly by NBA and the nine participating countries, with AfDB acting as an accredited entity.

The GEF-supported project "Integrated Development for Increased Rural Climate Resilience in the Niger Basin" aims at increasing water security, climate resilience, and management of natural resources at regional, sub-basin and community levels in the Niger Basin. In doing so, it contributes to the implementation of the SDAP as well as the NBA's Strategic Plan. Also, the German Federal Ministry for Economic Cooperation and Development (BMZ) is supporting the ongoing work of the NBA with the project "Transnational water management in the River Niger Basin" (2019-2021), implemented by GIZ. The focus is directed at the sustainable development of transboundary water resources in the Niger Basin, including the improvement of flood warning processes and identification of more than 200 climate-relevant projects by NBA.

Limpopo Basin

As part of the Southern African Development Community (SADC) "Revised Protocol on Shared Watercourses" framework, the riparian states of the Limpopo river basin, namely Botswana, Mozambique, South Africa and Zimbabwe, signed the Agreement for the Establishment of the Limpopo Watercourse Commission (LIMCOM) in 2003. Its main objective is to provide recommendations on the uses of the Limpopo, its tributaries and its waters for purposes and measures of protection, preservation and management of the river.

Programmes on supporting transboundary cooperation with relevance for addressing climate change or climate change impacts exist either to support the cooperation at the Limpopo directly or via the SADC framework. For instance, the German Federal Ministry for Economic Cooperation and Development (BMZ) and the UK Department for International Development (DFID) financed activities on improving water management and protection against droughts and floods in cooperation with SADC, implemented by GIZ (2016-2019).

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