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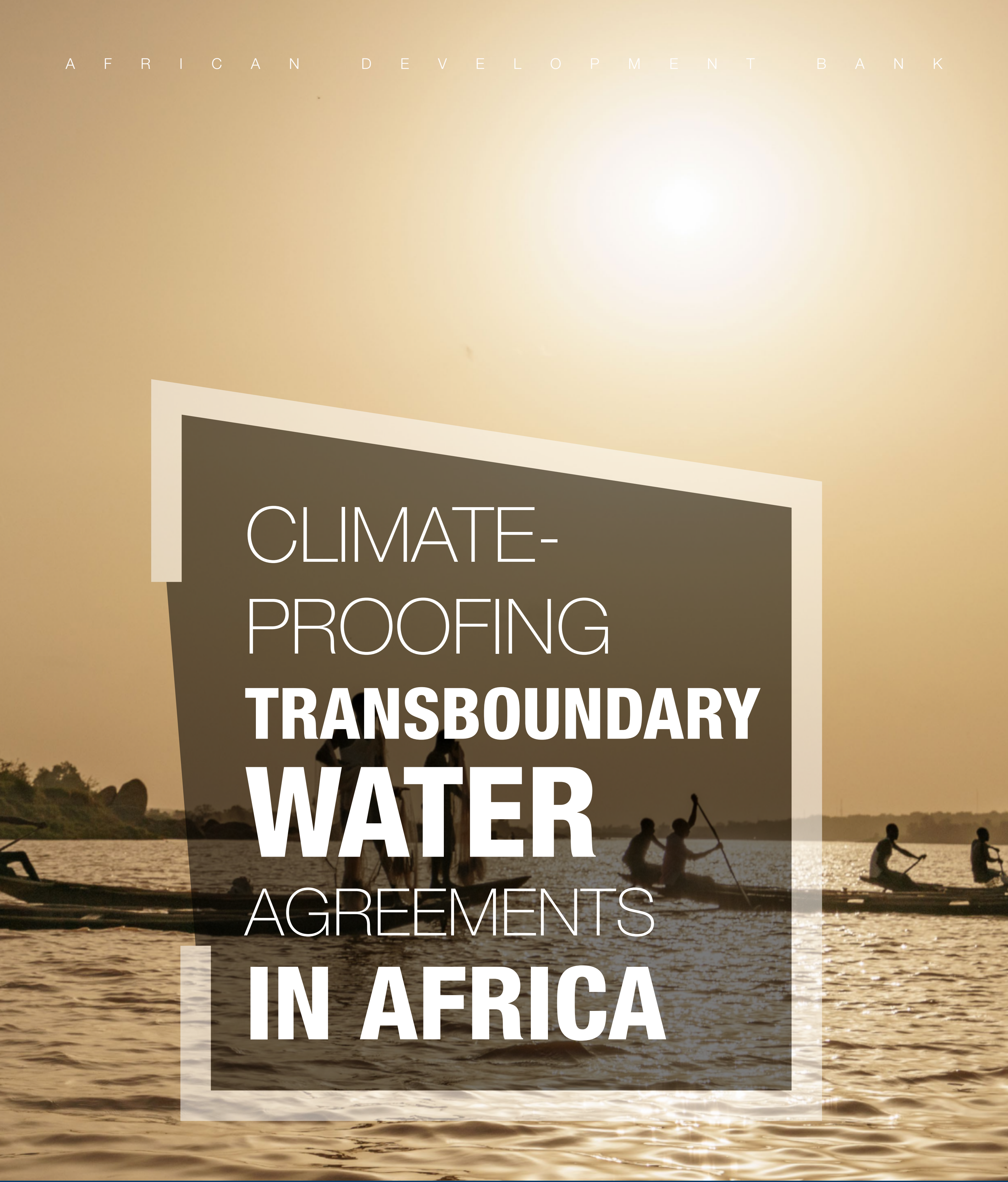

CLIMATE-PROOFING TRANSBOUNDARY WATER AGREEMENTS IN AFRICA

AFRICAN DEVELOPMENT BANK GROUP
GROUPE DE LA BANQUE AFRICAINE DE DÉVELOPPEMENT

September 2022

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ACRONYMS AND ABBREVIATIONS

$	US Dollars
BCM	Billion Cubic Metres
BCU	Basin Country Unit
CFA	Cooperative Framework Agreement
DOP	Declaration of Principles
EM-DAT	Emergency Events Database
GEF	Global Environment Facility
GERD	Grand Ethiopian Renaissance Dam
HAD	High Aswan Dam
IAEA	International Atomic Energy Agency
IBWC	International Boundary and Water Commission
ICPR	International Commission on the Protection of the Rhine
IGRAC	International Groundwater Resources Assessment Centre
IJC	International Joint Commission
IPCC	Intergovernmental Panel on Climate Change
IWRM	Integrated Water Resources Management
JPTC	Joint Permanent Technical Commission
LHWP	Lesotho Highlands Water Project
MOU	Memorandum of Understanding
NBI	Nile Basin Initiative
NSAS	Nubian Sandstone Aquifer System
NWSAS	Northwest Sahara Aquifer System
OP	Operational Priority
ORASECOM	Orange-Senqu River Commission
PWC	Permanent Water Commission
RBO	River Basin Organization
SADC	Southern African Development Community
SDG	Sustainable Development Goals
TBA	Transboundary Aquifer
TBR	Transboundary River Basin
TBW	Transboundary Water
TDA	Transboundary Diagnostic Analysis
TWAP	Transboundary Waters Assessment Programme
UN	United Nations
UNDP	UN Development Programme
UNECE	UN Economic Commission for Europe
UNEP	UN Environment Programme
UNESCO	UN Educational, Scientific and Cultural Organization
UNESCO-IHP	UNESCO- International Hydrological Programme
UNESCO-IOC	UNESCO - Intergovernmental Oceanographic Commission
UNILC	UN International Law Commission
UNWC	UN Watercourses Convention
VBA	Volta Basin Authority
VNJIS	Vioolsdrift and Noordoewer Joint Irrigation Scheme
WRM	Water Resources Management
ZAMCOM	Zambezi Watercourse Commission

FOREWORD

In the face of growing global concerns over the effects of climate change on water availability, climate-proofing transboundary water agreements is a unique solution for climate change adaptation. This is especially true in Africa, where 90% of surface water falls within shared river basins, 40% of the continent is situated on aquifers supporting more than one country, and where the continent continues to be affected by extreme weather events which put additional strain on already fragile safety nets and infrastructure. African countries now spend between 2% and 9% of their GDP in responding to climate-related events such as floods and droughts. For these countries, leveraging climate change adaptation solutions to support sustainable development goals, to integrate into Nationally Determined Contributions and National Adaptation Programme of Action strategies, and to improve water security, represents a major opportunity.

In transboundary waters, solutions developed to adapt to climate change can be leveraged to attain sustainable development goals and tackle water security issues that hinder economic and social development.

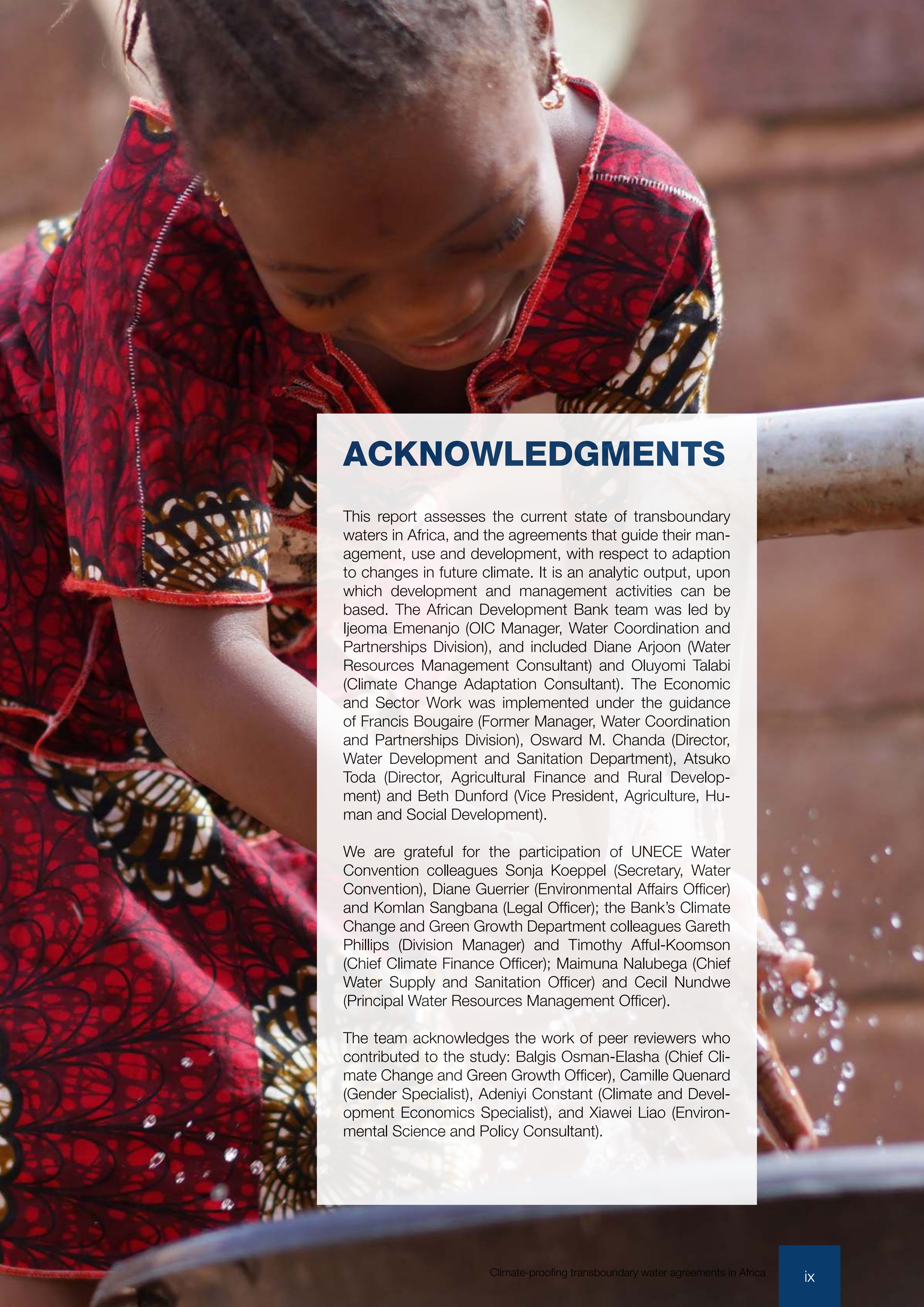
Climate-proofing allows for flexibility in the application of the rules and regulations defined in transboundary water agreements, enabling an easier adjustment to the consequences of climate change and can result in a more predictable water supply, greater incentives to develop, and more effectively manage and operate, necessary water storage infrastructure, and more transparent and accountable water institutions. It also increases water and food security and ecosystem protection, and promotes overall cooperation between riparian countries.

This report assesses the current state of transboundary waters in Africa, with respect to their susceptibility to the effects of climate change, and reviews how the agreements guiding their management, use and development support climate adaptation. Global lessons on the mechanisms in agreements which can support management of the variability of water resources caused by climate change are highlighted and a discussion on how such mechanisms can be applied to agreements on African transboundary waters is subsequently presented.

The findings of this research highlight opportunities for making transboundary water agreements more flexible, based on an examination of strategies for managing or reducing uncertainty in water supply. These include strategies for flexible water allocation, such as allocating water based on a percentage and timing of flow and specifying a minimum downstream delivery; flexibility in allowing changes to water allocation through escape clauses and amendment or review mechanisms; strategies for reducing uncertainty in water supply such as predictive modeling and joint management institutions; and leveraging enabling conditions for the proper application of rules and requirements defined in the agreements, including capacity building, enforcement and conflict resolution.

Finally, the report underscores the critical role of financing to support necessary climate-proofing of transboundary water agreements in Africa to ensure water security now and into the future.

Osward M. Chanda
Ag. Director, Water Development and Sanitation Department
African Development Bank



ACKNOWLEDGMENTS

This report assesses the current state of transboundary waters in Africa, and the agreements that guide their management, use and development, with respect to adaption to changes in future climate. It is an analytic output, upon which development and management activities can be based. The African Development Bank team was led by Ijeoma Emenanjo (OIC Manager, Water Coordination and Partnerships Division), and included Diane Arjoon (Water Resources Management Consultant) and Oluyomi Talabi (Climate Change Adaptation Consultant). The Economic and Sector Work was implemented under the guidance of Francis Bougaire (Former Manager, Water Coordination and Partnerships Division), Osward M. Chanda (Director, Water Development and Sanitation Department), Atsuko Toda (Director, Agricultural Finance and Rural Development) and Beth Dunford (Vice President, Agriculture, Human and Social Development).

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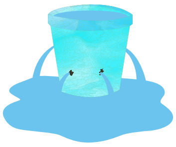
EXECUTIVE SUMMARY

Financing, to support the climate-proofing of transboundary water agreements in Africa, will play a critical role in ensuring water security in Africa, now and in the future.

Sustainable socio-economic development is founded on water security which is vital for food and energy production, health, and livelihoods and enables industrial development, liveable cities, global biodiversity and sustainable ecosystems.

Currently, one in every three people in Africa faces water insecurity. Only 58% of Africans have access to safely managed drinking water services. This figure is even lower in sub-Saharan Africa where, in 2017, only 27% of people had access to potable water. Across the continent, 72% of people lack basic sanitation services. As a result, there is a high incidence of disease that reduces human vitality and the overall economic productivity of Africa. The transformational potential of water is enormous, considering less than 5% of cultivated land is irrigated today and only 10% of hydroelectricity potential in Africa is utilized.



1 in every
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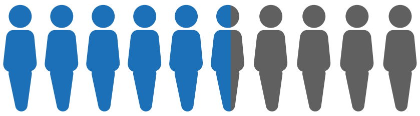


Only 58%
of Africans

have access to safely managed drinking water services

72% of people

lack basic sanitation services

Climate change further amplifies water-related development challenges in Africa through changes in water regimes and increases in water-related natural disasters, such as floods and droughts. The risks climate change poses to water resources and, by extension, food security, human health and ecosystem health and services, will have increasingly severe consequences on African lives and the prospects of driving increased sustainable development. Managing these risks will require careful interventions and longer-term strategies to mitigate, and adapt to, the effects of a changing climate.

The risks climate change poses to water resources and, by extension, food security, human health and ecosystem health and services, will have increasingly severe consequences on African lives and the prospects of driving increased sustainable development.

Realizing Africa's significant development potential depends on the sustainable management and use of transboundary water (TBW) resources. Transboundary river basins (TBRs) cover 62% of the total area of the African continent with 90% of surface water in Africa falling within 63 TBR catchments. Furthermore, transboundary aquifers (TBAs) underlie 40% of the continent's land, which are inhabited by 33% of the population (381 million). Tapping into Africa's TBW resources will significantly strengthen water security, improve livelihoods, and fuel economic growth in the region. Effective, sustainable and cooperative management and development of these resources is the key to unlocking dramatic improvements for Africa's people

Across the globe, water agreements between countries sharing a TBW resource often constitute the main governing apparatus in the use, development and management of shared water resources and are also used to promote transboundary cooperation through the joint management of shared water resources. In Africa however, only 29% of TBRs and fewer than 10% of TBAs are the object of TBW agreements and, of these, only 19% have any basin-wide agreements.

Most TBW agreements are based on an assumption that future water supply and quality will not change and often therefore, lack the capacity to adapt to changes.

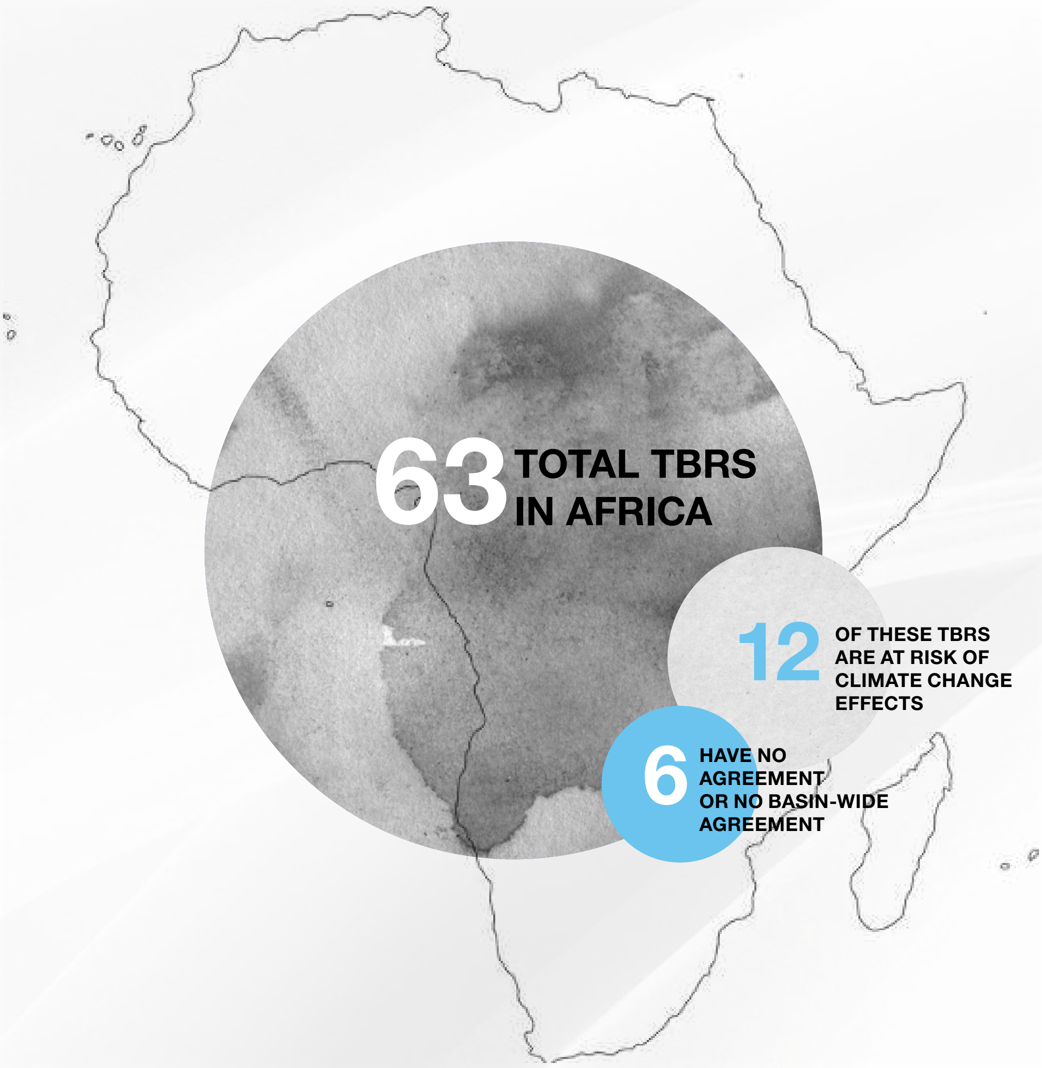
The benefits of improved cooperation over the use and management of TBWs include accelerated economic growth, improved human well-being, enhanced environmental sustainability, and increased political stability, and these same outcomes could be at risk as most existing TBW agreements fail to even consider increasing climate-induced water variability. Most TBW agreements are based on an assumption that future water supply and quality will not change and often therefore, lack the capacity to adapt to changes. Empirical evidence already suggests that the likelihood of political tensions over shared water resources is related to the interaction between resource variability and the lack of institutional capacity to absorb or manage the change. In situations in which resource availability falls below levels allocated in a treaty, non-compliance can follow, which may give rise to geo-political tensions and affect the credibility and trust built through TBW agreements, leading to deteriorating inter-state relationships.

Climate-proofing a TBW agreement refers to the incorporation of clauses and provisions within an agreement to ensure the sustainability of the defined rules, regulations, procedures, and processes and allows for built-in flexibility to adjust to the consequences of climate change. Flexible agreements can result in more predictable water supply to all riparian states, greater incentives to develop necessary water storage infrastructure and to effectively manage the operation of existing infrastructure, and more transparent and accountable water institutions. Other major outcomes include increased water and food security, environment and ecosystem protection, and the reduced need for complex and burdensome legal, administrative and enforcement activities.

TBW agreements in Africa will require climate-proofing to ensure the efficient, equitable and sustainable management and development of these resources and, at the same time, to protect basin communities from the economic and social implications of increasingly common extreme events, such as droughts and floods, and changes in water availability.

Climate-proofing a TBW agreement refers to the incorporation of clauses and provisions within an agreement to ensure the sustainability of the defined rules, regulations, procedures, and processes and allows for built-in flexibility to adjust to the consequences of climate change.

Drawing on existing studies, literature and data, this report examines TBW agreements in Africa and uncovers mechanisms for climate-proofing existing and future agreements to enable climate change adaptation. The context of climate change effects on water supply is outlined. This is followed by an evaluation of TBW resources in Africa, to assess their risks from water supply variability, followed by an assessment of existing TBW agreements. Mechanisms within the agreements are analysed, which have varying degrees of success in allowing adaptations to manage climate change impacts. Finally, an evaluation of climate-proofing strategies is presented, recommendations are made on climate-proofing existing TBW agreements, and guidance to be considered in preparing new agreements is proposed.



The analyses reveal that 12 of the 63 TBRs in Africa are considered at-risk for climate change effects. Of these, half have no agreement or no basin-wide agreement, making the management of these river basins difficult and the risk for adverse climate change effects very high. The situation with TBAs in Africa is also grim. Of the 6 TBAs that are considered to be "hotspots", only 2 currently have agreements and only 1of these is a fully scoped agreement signed by all parties.

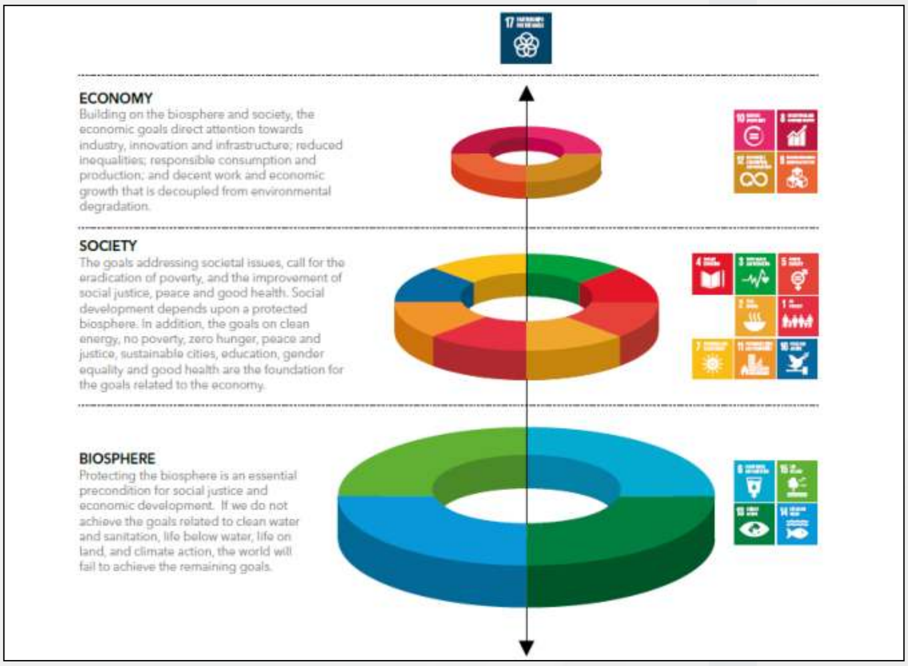
Establishing and implementing TBW agreements is a complex process requiring lengthy negotiations between basin states covering a range of issues, where full agreement is sometimes difficult to reach. Once established, the implementation of these agreements is subject to continual changes in resource availability, through climate-induced water supply variability or changing demand due to economic development and growing populations. The omission of mechanisms to adapt to these changes has serious implications for the current and future management of TBWs. Agreements with fixed rules and procedures impede the effective and sustainable management of resources, mainly through the risk of a breakdown in cooperation between riparian states as promised allocations and benefits become effectively unobtainable.

1 INTRODUCTION

Water security is a cornerstone of sustainable socio-economic development and is a vital input for food and energy production, health, livelihoods, and enables industrial development, liveable cities, global biodiversity and sustainable ecosystems. UN-Water[1] defines water security as "the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability".

In fact, when considering the importance of water security in the United Nations 2030 Agenda for Sustainable Development, Pretlove and Blasiak argue that "Protecting the biosphere is an essential precondition for social justice and economic development. If we do not achieve the goals related to clean water and sanitation, life below water, life on land, and climate action, the world will fail to achieve the remaining goals"[2] (Figure 1-1). This highlights the critical role of water security not only for realizing SDG 6 (ensure access to water and sanitation for all), but also for the achievement of many sustainable development goals.

Figure 1.1. The supporting role of water in achieving the SDGs



SOURCE: Stockholm Resilience Center 2017

Currently, one in every 33 people in Africa faces water insecurity[3]. Only 58% of Africans have access to safely managed drinking water services[4] (the figure drops as low as 27% in sub-Saharan Africa in 2017[5]) and 72% lack basic sanitation services[6]. As a result, there is a high incidence of disease human vitality and the overall economic productivity of Africa[7]. Less than 5% of cultivated land is irrigated while Africa is the only continent where the population growth rate has outpaced the growth rate of food production[8]. At the same time, people in sub-Saharan Africa suffer the lowest electrification rate on the continent, with about 600 million people without access to electricity[9], while only 10% of hydroelectricity potential in Africa is currently utilized.

1 UN-Water. 2013. Water security and the global water agenda. Analytical brief.
2 Pretlove B and Blasiak R. 2018. Mapping ocean governance and regulation. Working paper for consultation for UN Global Compact Action Platform for Sustainable Ocean Business. Technical Report.
3 Mason, N., Nalamalapu, D. and Corfee-Morlot, J. (2019) Climate change is hurting Africa's water sector, but investing in water can pay off. World Resources Institute.
4 https://www.worldbank.org/en/programs/cooperation-in-international-waters-in-africa
5 WHO/UNICEF Joint Monitoring Programme (JMP) for Water Supply, Sanitation and Hygiene
6 Sanitation Overview (worldbank.org)
7 The Africa Water Vision 2025.
8 Chayes, A. and Chayes, A. (1993) On compliance. International Organization, 47, 175–205
9 Castellano et al. (2015) Powering Africa. McKinsey & Company.

The benefits of cooperating on the use and management of TBWs include accelerated economic growth, improved human well-being, enhanced environmental sustainability, and increased political stability

Climate change amplifies water-related development challenges in Africa, through changes in water regimes and increases in water related disasters such as floods and droughts. Africa is one of the most vulnerable continents to climate change effects due to its high dependence on ecosystem goods and services for livelihoods and its weak adaptive capacity. The risks of climate change on water resources and, by extension, food security, human health and ecosystem health and services, will have increasingly severe consequences on African lives and sustainable development prospects[10]. Managing these risks will require new strategies to mitigate the effects of a changing climate and to adapt to them.

Realizing the development potential in Africa depends on the sustainable management and use of TBW resources such as aquifers, lakes and river basins. TBRs cover 62% of the total area of the African continent (the highest area of all continents)[11]. 90% of the surface water in Africa falls within 63 TBR catchments[12] (Figure 1-2). Furthermore, TBAs underlie 40% of the continent (Figure 1-3), and 33% of the population (381 million) live on these aquifers[13]. Tapping into Africa's tremendous, shared water resources has the potential to significantly strengthen water security, improve livelihoods, and fuel economic growth in the region, but its success will rely on effective, sustainable and cooperative management and development.

Globally, water agreements between countries sharing a TBW resource often constitute the main governing apparatus in the use, development and management of shared water resources and are used to promote transboundary cooperation through the joint management of shared water resources[14]. Although signing a treaty does not guarantee a future of stable cooperation, it nevertheless provides riparian states with a structured means of organizing their affairs and managing disputes in an attempt to avoid conflicts[15]. Treaties create a framework for interactions between different stakeholders and establish mutually accepted relationships and expectations of behaviours[16]. Studies using empirical data, have demonstrated that it is not only the presence of treaties that promotes cooperation in TBRs and TBAs, but also the number of these[17]. In Africa, however, only 29% of the TBRs and fewer than 10% of the TBAs are the object of TBW agreements and, of these, only 19% have any basin-wide agreements.

The benefits of cooperating on the use and management of TBWs include accelerated economic growth, improved human well-being, enhanced environmental sustainability, and increased political stability. Such advantages can be considered at risk, given that most existing TBW agreements fail to consider potentially increasing water variability due to climate change. Most TBW agreements assume that future water supply and quality are unchang-

10 Niang, I., O.C. Ruppel, M.A. Abdrabo, A. Essel, C. Lennard, J. Padgham, and P. Urquhart, 2014: Africa. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment.

11 Cooley & Gleick, 2011. Climate-proofing transboundary water agreements

12 Source: https://www.worldbank.org/en/programs/cooperation-in-international-waters-in-africa. Note that the 2018 update of the TBR register indicates that there are now 68 TBRs in Africa. The most commonly cited number is 63, which resulted from a 2016 update of the register. These numbers have changed over time and represent a snapshot in time of the rivers that meet the criteria to be considered "international" or "transboundary". Changes to political borders and increases in remote sensing technology are the 2 primary reasons for the increase in number of international river basins.

13 Nijsten GJ, Christelis G, Villholth KG, Braune E and Gaye CB. 2018. Transboundary aquifers of Africa: Review of the current state of knowledge and progress towards sustainable development and management. Journal of Hydrology: Regional Studies 20: 21-34.

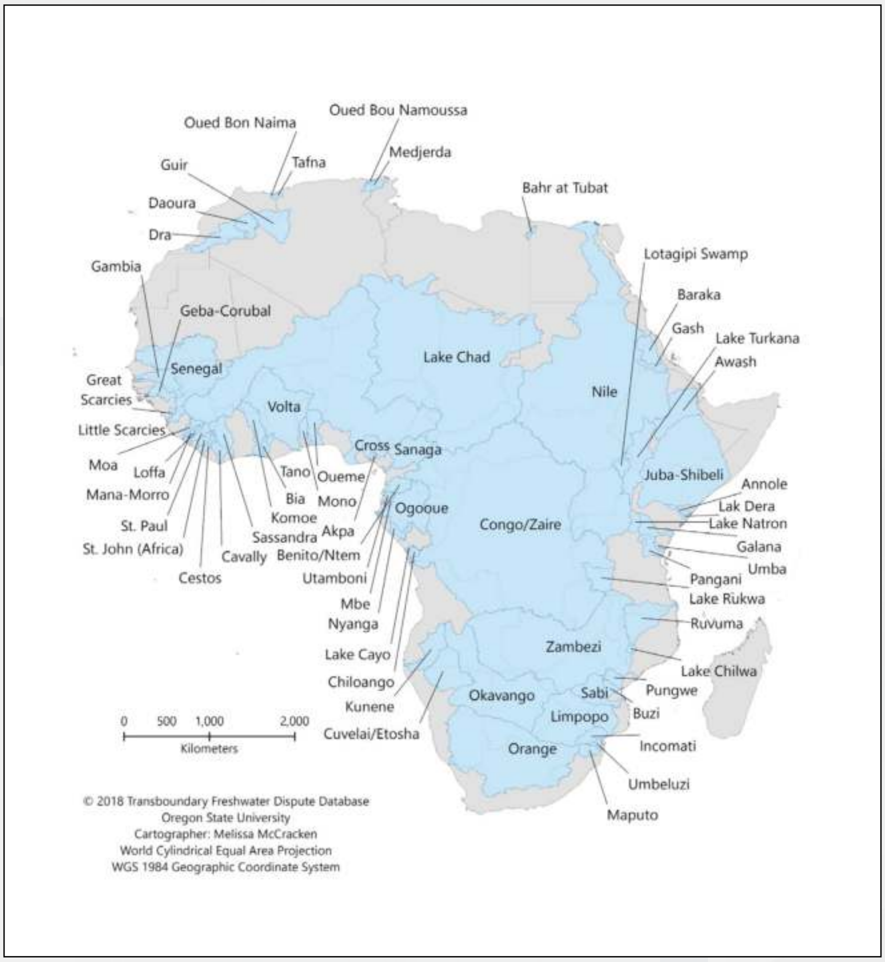
14 Brochmann, M. (2012). Signing river treaties: Does it improve cooperation? International Interactions, 38, 141–163.

15 Weiss, Edith Brown, and Harold K. Jacobson. 1998. Engaging Countries: Strengthening Compliance with International Environmental Accords. Cambridge, MA: The MIT Press

16 Chayes, A. and Chayes, A. (1993) On compliance. International Organization, 47, 175–205

17 Dinar, S., Katz, D., De Stefano, L. and Blankspoor, B. (2016) Climate change and water variability. Do water treaties contribute to river basin resilience? World Bank.

Figure 1.2. International river basins in Africa



ing[18] and they often lack the capacity to adapt to such potential changes. Empirical evidence already suggests that the likelihood of political tensions over shared water resources is related to the interaction between resource variability and the lack of institutional capacity to absorb the change[19]. In situations in which resource availability falls below levels allocated in a treaty, non-compliance can occur, which may not only give rise to geo-political tensions, but also affect the credibility and trust previously built through TBW agreements, and lead to deteriorating international relationships. Without effective cooperation, competing interests among different riparian states can lead to a tragedy of the commons, resulting in the degradation of water resources as a common pool resource and, even more importantly, adversely affect development opportunities across the basin.

Compared to developed nations, a lack of appropriate funding and infrastructure in developing countries results in a much smaller capacity to respond to climate change effects, including water related disasters, and to recover afterwards. Without sufficient resilience, water-related challenges threaten to erase hard-earned development gains.

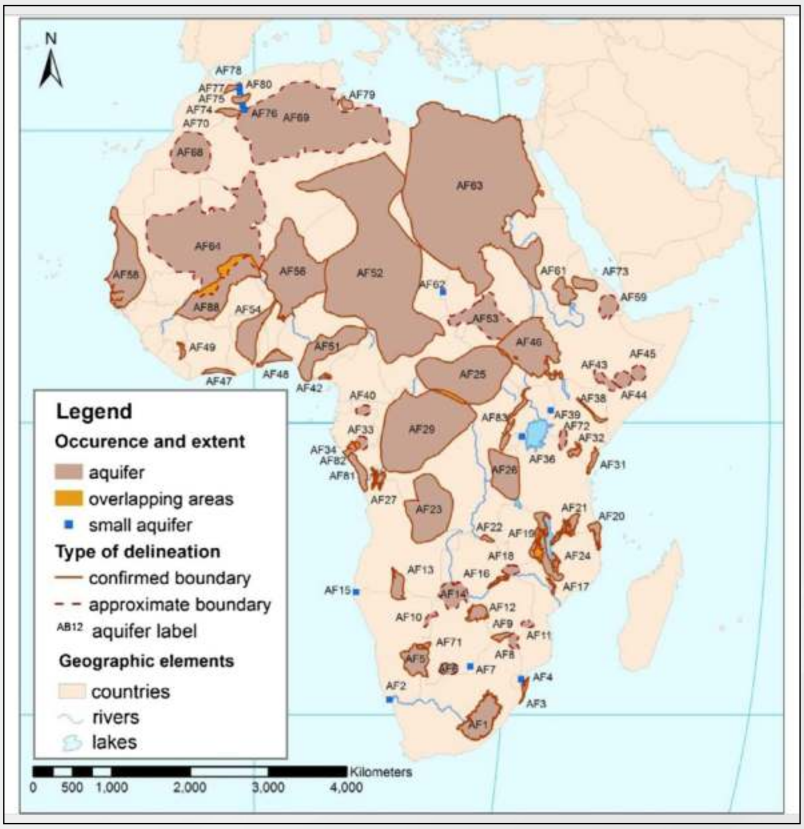
Recently, the African Development Bank has supported African countries in their capacity to cope with water-re-

Treaties create a framework for interactions between different stakeholders and establish mutually accepted relationships and expectations of behaviours.

18 Cooley & Gleick, 2011. Climate-proofing transboundary water agreements

19 Wolf, A., Stahl and Macomber (2003) Conflict and cooperation within international river basins: the importance of institutional capacity. Water Resources Update 125, 31-40.

Figure 1.3. Transboundary aquifers in Africa



SOURCE: IGRAC, UNESCO-IHP, 2015a. Transboundary aquifers of the world [map]. 15 Scale 1: 50 000 000, edition 2015. IGRAC, Delft, Netherlands.)

lated challenges through the development of its Water Strategy, which sets the vision of a "water secure Africa where there is equitable and sustainable use and management of water resources for quality socio-economic transformation" and the goal of "increased water security for Africa, where transformed water resources foster sustainable, green and inclusive socio-economic growth and development". The strategy is anchored on 4 strategic objectives (called pillars) (Figure 1.4) that support: the achievement of the High 5 development priorities of the Bank (Light up and Power Africa, Feed Africa, Industrialize Africa, Integrate Africa, and Improve the Quality of Life for the People of Africa) (Figure 1.5); the operationalization and implementation of the Water Policy; and the importance of water across multiple sectors. Strategic Pillar (SP) 1 of the strategy aims to assess, plan, and safely manage water resources for all social, economic, and environmental uses. The other 3 pillars correspond to the focus areas of engagement defined in the African Development Bank's Policy on Water. To effectively deliver SP1, the Bank will focus on 3 Operational Priorities (OPs) including: the assessment of water resources and integrated planning of surface water and groundwater resources (OP1); the strengthening of regional and national institutions for cooperative management of shared waters (OP2); and strengthening resilience to water-related disasters, climate variability and climate change through risk management, technology, and infrastructure.

1.1 OBJECTIVES

The purpose of this report is to (i) review the state of TBWs in Africa to assess their susceptibility to the effects of climate change; (ii) review the state of current agreements guiding the management, use and development of TBWs in Africa; and (iii) highlight global learnings on the mechanisms in agreements which manage the variability of water resources due to climate change and consider how these can be applied to agreements that cover at-risk basins and aquifers in Africa.[20]

20 This is a desk study, using available literature, data and information, to analyze transboundary rivers and aquifers in Africa, and the legal agreements driving their development and management. Data on international rivers and aquifers in Africa, used in this study, is found in the Global Environment Facility's Transboundary Waters Assessment Programme (TWAP) (http://geftwap.org/twap-project) which provides a baseline assessment of transboundary rivers for a number of indicators and UN-IGRAC's system on transboundary aquifers (https://www.un-igrac.org/ggis/transboundary-aquifers-twap-project). Data for legal agreements on transboundary rivers is found in the International Freshwater Treaties Database, housed at Oregon State University (https://transboundarywaters.science.oregonstate.edu/content/international-freshwater-treaties-database).

Figure 1.4. Four strategy pillars of the Bank's Water Strategy

SP1 Integrated and Sustainable Water Resources Management

OP1 Water resources assessed and comprehensively planned for both surface water and groundwater resources

OP2 Regional and national institutions for managing water established and/or supported

OP3 Country and regional systems for resilience to water related disasters and climate change built

SP2 Water Supply, Sanitation, & Hygiene services

OP4 Countries supported to reform and strengthen WASH governance

OP5 Innovative financing and partnerships leveraged, incl.PSPs

OP6 Investments in resilient infrastructure and quality services for inscreased access to water supply

OP7 Investments in resilient infrastructure and quality services for inscreased access to sanitation

OP8 Behavior change and adoption of hygienne practices promoted

SP3 Water for Food

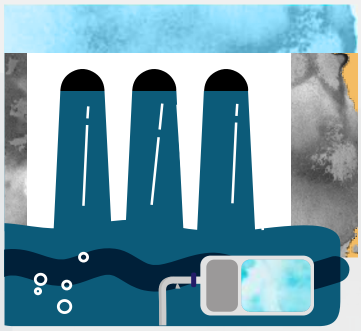
OP9 Countries supported to reform and strengthen enabling environment for managing water in agriculture

OP10 Investments in resilient infrastructure for increased agricultural water availability

OP11 Modern and appropriate technology in use for increased water productivity

OP12 Selected anchor investments for enhancing fisheries pursued

SP4 Water for Energy



OP13 Countries supported to reform and strengthen enabling environment for coordinated water and hydropower planning and development

OP14 Management Information Systems improved for effective water and hydropower planning and development

Figure 1.5. African Development Bank's High 5 priorities

The broader impacts from this report include:

- **Strengthening institutional capacity at the national, basin and regional levels, to adapt to climate change and its impacts on water resources, thereby enhancing water security.**
    - o Since water security underpins food and energy security, livelihoods and human health, this activity will also lead to improved adaptation capacities in these areas. Furthermore, climate-proofing water agreements will facilitate investment into climate resilient infrastructure, driven by improved data and information.
- **Increasing the bankability of project proposals by helping to account appropriately for climate change risks and complexities in TBW agreements.**
    - o Accounting for climate change risks and complexities is critical for preparing bankable project proposals ready to attract public and private financing partners. The versatility and effectiveness of existing TBW agreements is critical to the Bank's investments in TBW management organizations and programmes. Transboundary approaches inevitably bring additional risks and complexity to a project, with the involvement of multiple countries, multiple legal responsibilities for implementation, and the challenges of sharing up-stream or down-stream benefits and commitments. In order to be successful, investment projects must be supported by TBW agreements and policies, and these agreements must consider future climate change issues in their basins.
- **Contributing to the Bank's investment programmes by supporting the development of a cooperative environment for investment. This environment will be stimulated by informing data- and evidence-driven investment and sustaining and maximizing the impacts of investments.**
    - o Catalyzing a cooperative environment for investment: It is estimated that Africa will need to invest $93 billion per year in infrastructure development over the next decade to catch up with the rest of

the developing world[21] in terms of access to electricity, water supply and sanitation, transport, information and communications technology and irrigated food production. These infrastructure demands will largely come from areas that are located in TBRs and TBAs. Climate-proofing TBW agreements is, therefore, crucial for nurturing a broader cooperative geo-political environment for investment.

o Informing data- and evidence-driven investment: There is a current lack of understanding of the characteristics of TBWs in the African region, including both TBRs and TBAs, and the impacts they will face from future climate change. Improved understanding is required in order to better recognize the development challenges and demands, and to design effective solutions. TBW agreements should include provisions to facilitate joint studies and assessments that will advance our understanding of a range of important issues in TBWs in Africa including the hydrology, socio-economic, political economy, and climate change projections. Agreements should also include data sharing protocols and other mechanisms which will facilitate such studies. Capacity building, in terms of both human capacity and monitoring capacity, especially with advanced or disruptive technologies, is urgently required.

o Sustaining and maximizing the impacts of investment: The decision-making process to assess investments includes estimations of their impact and this has, to date, been based on a 'no climate change' presumption[22]. This presumption is untenable going forward. Water resources are required for infrastructure investments in hydropower production, water supply and sanitation, irrigation, and inland waterway transportation. It is now critical to mainstream climate change adaptation considerations in the complete infrastructure investment cycle (planning, design, preparation, construction and operation, maintenance). Climate-proofing TBW agreements would provide flexibility to mitigate the impacts of potential climate extremes and avoid lock-in effects and, therefore, enhance the resilience of investments as they face climate change impacts.

- **Contributing to the implementation of the Bank's Water Strategy and Policy on Water, and the achievement of the High 5 priorities by supporting institutions in building resilience to existing and future climate variability in the development and management of water resources.**

o The first strategic pillar of the Bank's Water Strategy provides for the integrated and sustainable management of water resources through the assessment and integrated planning of surface and groundwater (Operational Priority or OP 1); the strengthening of regional and national institutions to manage shared waters cooperatively (OP 2); and increasing resilience to water-related disasters, climate variability and climate change (OP 3). One of the cross-cutting areas defined in the water strategy is climate change, with inadequate legal frameworks identified as being among the major blockages to the development of effective response measures. Institutional initiatives, particularly the climate-proofing of policies and agreements, are an important step toward strengthen institutions as they build resilience to existing and future climate variability in the development and management of water resources.

o Management of TBW resources, that take into account climate adaptations, will strengthen regional integration by moving countries toward basin-wide development and joint projects (or national projects of basin-wide significance) which will enhance sub-regional sustainable growth and regional cooperation. This is in line with the Bank's climate change and green growth strategic framework, which assists Regional Member Countries and Regional Economic Communities to develop climate change adaptation and resilience strategies and integrate measures to tackle climate change impacts on water related sectors.

21 Cervigni R and Wishart M. 2013. Addressing the climate vulnerability of African Infrastructure.
22 World Bank. 2009. Africa's infrastructure: A Time for Transformation.

The next sections of this document present:

- **Climate change effects on water resources (Section 2).**

This section gives a general overview of how climate change affects water resources and presents the widescale effects of climate change in Africa.

- **TBW resources in Africa (Section 3).**

This section provides a situational analysis of TBW resources in Africa. TBRs and TBAs are analysedanalysed with respect to their risk levels, based on a number of indicators pertinent to climate change effects. Results of an analysis of TBW agreements, to assesses their vulnerability to climate change, is also presented.

- **Climate-proofing transboundary agreements (Section 4).**

In this section, an examination of mechanisms for climate change adaptability in TBW agreements, based on case studies and international best practices, is made. From this examination, and a review of current literature, a summary of mechanisms to be considered for climate-proofing TBW agreements is proposed. TBW agreements driving development and management of the most at-risk TBRs and TBAs in Africa are analysed in detail, especially those which have the strongest potential to enable climate change adaptation.

- **Recommendations (Section 5).**

Specific recommendations are made for TBRs and TBAs in Africa that are of critical importance and facing climate change risks, based on the earlier analyses. For TBRs and TBAs without existing TBW agreements, recommendations are made for their development with climate change considerations incorporated. For those with existing agreements, recommendations on reshaping these for climate change adaptation are presented.

2 CLIMATE CHANGE EFFECTS ON WATER RESOURCES

Water is the stress multiplier in Africa. It is central to human and economic well-being and the increasing impacts of climate change affect livelihoods, economies, ecosystems and the entire health, agriculture, and energy sectors. Climate change and water development decisions manifest in stressed water resources (Box 2.1). Poor governance and inadequate water management further undermine water security as they invariably lead to conflict and overuse.

Understanding the impacts of a changing climate on TBWs is of paramount significance for developing appropriate adaptation strategies. Climate change has substantial impacts on the earth, affecting the global hydrologic cycle. Higher average temperatures, temperature extremes and changes in patterns and amounts of precipitation affect the temporal and spatial availability of water resources, affect water quality, and drive changes to aquatic resources (Figure 2.1). Globally, the situation is complicated by the fact that different regions, river basins, lakes and ecosystems are affected to different degrees, varying rates and in a variety of ways, and this irregular and unpredictable pattern of effects is likely to continue.

Box 2.1. Global climate change effects - Facts and Figures

By 2050 The number of people at risk from flooding will increase from its current level of 1.2 billion to 1.6 billion.
In the early to mid-2010s, 1.9 billion people, or 27% of the global population, lived in areas of potential severe water-scarcity. In 2050, this number will increase to 2.7 - 3.2 billion people.

Climate change is projected to increase the number of water-stressed regions and exacerbate shortages in regions of existing water-stress.
More than two billion people live in countries experiencing high water stress. The situation will likely worsen as populations and the demand for water grow, and as the effects of climate change intensify.

With the existing climate change scenario, by 2030, water scarcity in some arid and semi-arid places will displace between 24 million and 700 million people.

Scientists, farmers, and the business community consider water variability, in the form of "extreme weather events", one of the highest risks to food production over the next ten years.

2.1 EFFECTS OF A CHANGING CLIMATE ON WATER DEMAND AND SUPPLY

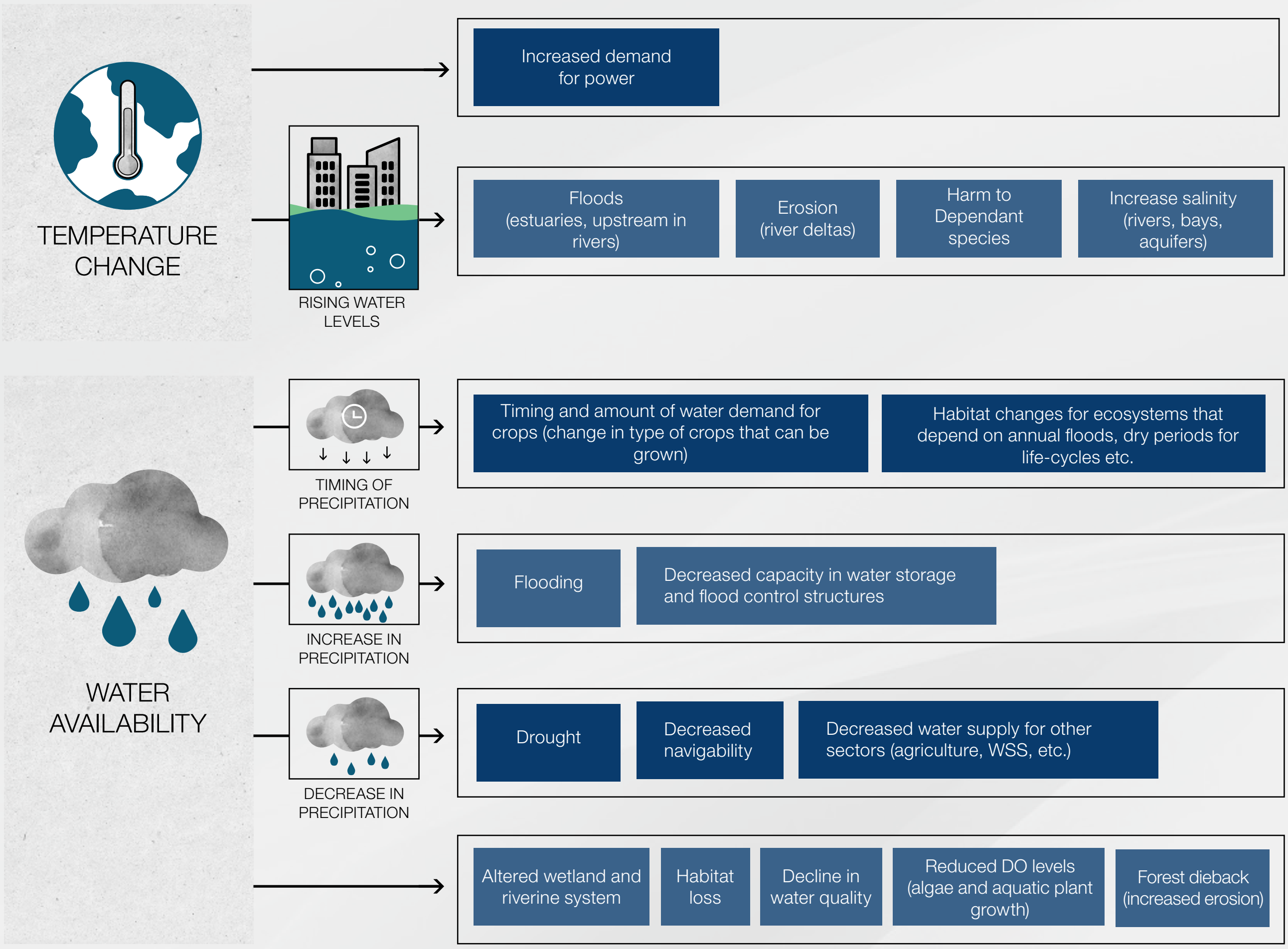
2.1.1 Warming air and water temperatures

Warming air and water temperatures have a significant effect on water supply, water demand and water quality in rivers and reservoirs. Warming air increases the demand for power, for cooling purposes, and the demand for water for human and livestock consumption. Increases in air temperatures will also affect the types of crops that can be grown in a region, and the timing and amount of water required to sustain crops as transpiration increases. If the temperature of water received in thermoelectric power plants is too high, it can cause shut downs, and the efficiency of production reduces as intake water temperature and ambient air temperatures rise[23], both of which can result in unmet power demands from growing populations. Increases in river and lake temperatures can also affect water quality and increase the growth of algae and other aquatic plants, thereby reducing dissolved oxygen levels and harming aquatic life.

On the supply side, critical headwaters of major rivers and other freshwater sources, such as mountain glaciers and snowpack, are melting at unprecedented rates due to warming air temperatures. In the future, more precipitation at higher elevations will fall as rain, rather than snow, which will lead to reduced water availability due to faster and higher runoff compared to the slow steady water releases from glaciers and snowpack. The faster runoff will reduce the levels of soil moisture and groundwater recharge. Additionally, reservoirs (whether natural or man-made) are subjected to increased rates of evaporation with consequences such as drying lakes, decreased hydro-electric power production and decreases in water supply from multi-purpose reservoirs.

23 Liu L. 2015. Climate change impacts on thermoelectric-power generation in the United States. American Geophysical Union, Fall Meeting 2015

Figure 2.1. Climate change effects on water supply, water demand and aquatic ecosystems



The global mean sea level has risen about 21-24 cm since 1880, with about one third of that occurring in the last 25 years.

Warming air and water temperatures also have a serious effect on sea levels due to meltwater from glaciers and ice sheets, and the thermal expansion of seawater as it warms. The global mean sea level has risen about 21-24 cm since 1880, with about one third of that occurring in the last 25 years. In 2019, global mean sea level was 8.7 cm higher than the 1993 average, and from 2018 to 2019, the sea level rose by 0.6 cm. It is predicted that, at a minimum (meaning a low carbon pathway), global sea levels will likely rise at least 30 cm above the 2000 levels by the end of the century[24].

Even a small rise in sea level will inundate estuarine wetlands; accelerate erosion of low-lying river deltas; increase salinity in rivers, bays, and aquifers; and increase flooding from storm surges. As a result, ecosystems will likely be harmed, including wildlife that is dependent on wetlands, such as molluscs and waterfowl. Nations situated downstream in international river basins will be particularly disadvantaged by their position on the river and under pressure from a rising sea level.

2.1.2 Spatial and temporal precipitation changes

Climate change directly affects spatial and temporal patterns of precipitation and therefore, the quantity and quality of water resources available to meet the needs of societies and ecosystems. Increases in rainfall intensity results in greater peak flows but less groundwater recharge while greater amounts of precipitation can lead to flooding in river basins and lakes. Current reservoirs and flood-control structures may not have been designed to deal with additional quantities of water. Decreases in precipitation, on the other hand, can affect the navigability of rivers and cause a decline in water quality as pollutants become more concentrated. In either case, aquatic

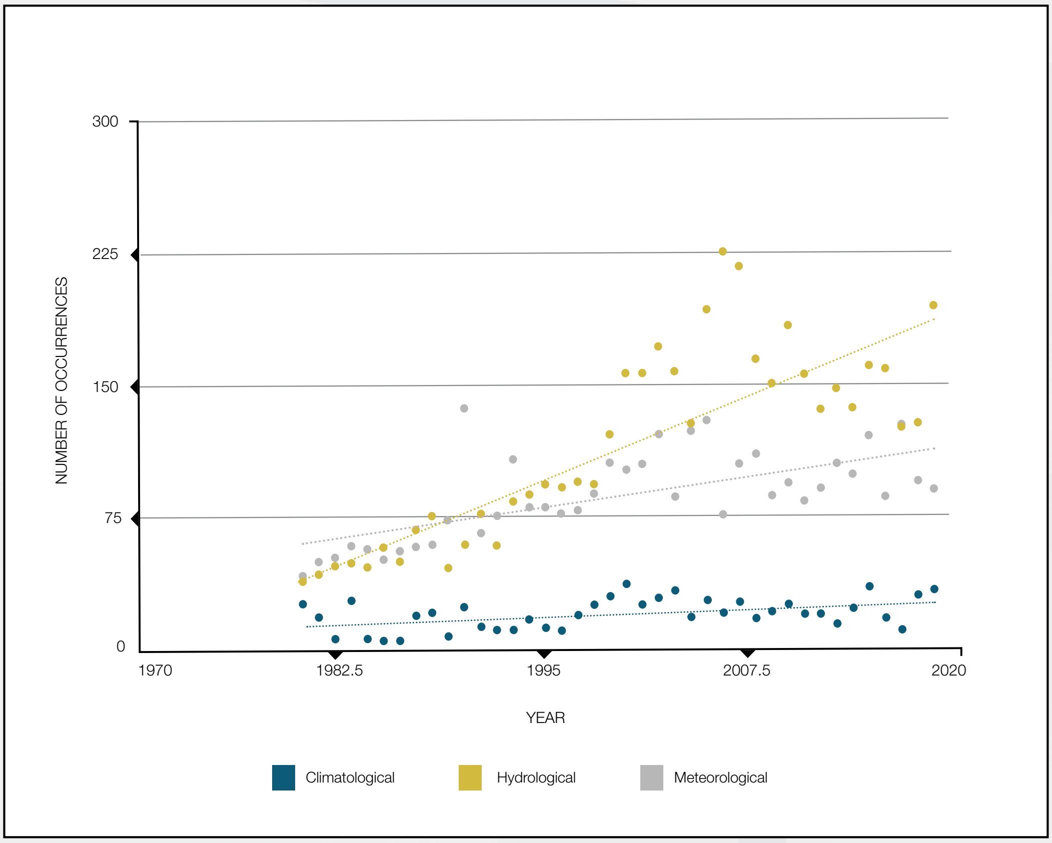
24 https://www.climate.gov/news-features/understanding-climate/climate-change-global-sea-level

Increases in rainfall intensity results in greater peak flows but less groundwater recharge while greater amounts of precipitation can lead to flooding in river basins and lakes.

ecosystems will be altered, resulting in changes to their proper functioning and increased loss of biodiversity and damage to ecosystem services. Forests are also vulnerable to the effects of climate change and dieback could occur. The loss of forests invariably results in higher levels of run-off to watercourses and increased soil erosion.

Increases in the frequency and intensity of extreme weather events, world-wide, have resulted in a substantial increase in flooding, droughts, and storms. Globally, hydrological events (floods) have almost quadrupled since 1980 (Figure 2.2). Climatological events, such as extreme temperatures and droughts, and meteorological events (storms) have increased by 1.4 and 0.3 times, respectively, in the same period. At the same time, demographic changes are exposing more people to these hazards.

Figure 2.2. Number of climatological, hydrological, and meteorological events, globally (1980-2019)



SOURCE: EM-DAT, CRED / UCLouvain, Brussels, Belgium www.emdat.be (D. Guha-Sapir)

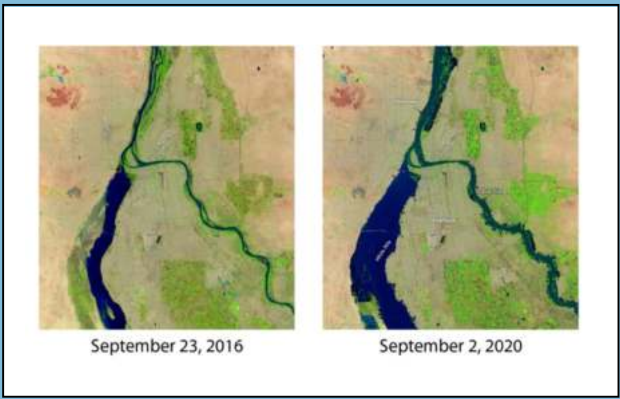
2.2 CLIMATE CHANGE IN AFRICA

Africa is one of the most vulnerable continents to the variabilities of climate change. Temperatures in Africa have risen quickly over recent decades, with the year 2019 being among the 3 warmest years on record. Annual rainfall has varied enormously over the continent, with rainfall in Southern Africa and west of the High Atlas Mountains well below the long-term means, yet above average means recorded in Central and East Africa. There has also been significant regional variability in sea-levels around Africa. Levels in the south-western Indian Ocean, from Madagascar eastward toward Mauritius, have increased by more than 5 mm/year, which is more than the global sea-level rise of 3-4 mm/year. In 2019 and 2020, Africa was hit by several extreme weather events, including Cyclone Idai which was one of the most destructive tropical cyclones ever recorded in the southern hemisphere. Along with Cyclone Kenneth, which hit the same region one month later, Cyclone Idai resulted in a large number of casualties, displaced persons and widescale damage. The region of Southern Africa was the most severely affected by drought in 2019. In contrast, the Greater Horn of Africa had a dramatic shift from very dry conditions in 2018/2019 to heavy rains and flooding in late 2019. Flooding also affected the Sahel and surrounding areas in mid-2019.[25] This variability in climate is one of the key drivers of recent increases in food insecurity on the continent, together with instability from conflicts, endemic poverty, and complex governance and institutional dimensions.

25 Information in this paragraph has been taken from World Meteorological Organization. 2020. State of the Climate in Africa 2019. WMO-No. 1253.

Box 2.2..Extreme climate events of importance in Africa (2019, 2020)

Floods in Sudan (2020)



SOURCE: NASA Earth Observatory (https://earth.org/data_visualization /sudan-floods-2020/)

In September 2020, monsoon rains in Ethiopia caused a devastating flood across Sudan with the Blue Nile reaching more than 17 meters, the highest level in almost a century.

The rain and floods are among the most severe recorded in the region, exceeding records set in 1949 and 1988.

17 of Sudan's 18 states experienced flooding; Khartoum State was one of the worst-hit.

More than 100 deaths
110 000 homes destroyed or damaged, 650,000 people affected.

Cyclone Idai (2019)

SOURCE: NASA Earth Observatory (https://earth.org/data_visualization /sudan-floods-2020/)

Cyclone Idai is the deadliest tropical cyclone recorded in the South-West Indian Ocean basin. The long-lived storm caused catastrophic damage, and a humanitarian crisis in Mozambique, Zimbabwe, and Malawi. The cyclone:

→ Caused catastrophic flooding, landslides, and large numbers of casualties across Mozambique, Malawi, and Zimbabwe
→ Inundated more than 360,000 hectares (900,000 acres) of crops, and damaged at least 17,000 houses and dozens of health units, in Mozambique
→ Knocked out transmission lines in Mozambique that carry power to South Africa

90% of the city destroyed
Heavily damaged the city of Beira, Mozambique

Drought in Southern Africa (2019)

SOURCE: NASA Earth Observatory (https://earth.org/data_visualization /sudan-floods-2020/)

Diminished and late rainfall, combined with long-term increases in temperatures, have jeopardized the food security and energy supplies of millions of people, mostly in Zambia and Zimbabwe.

11 million people
faced food shortages

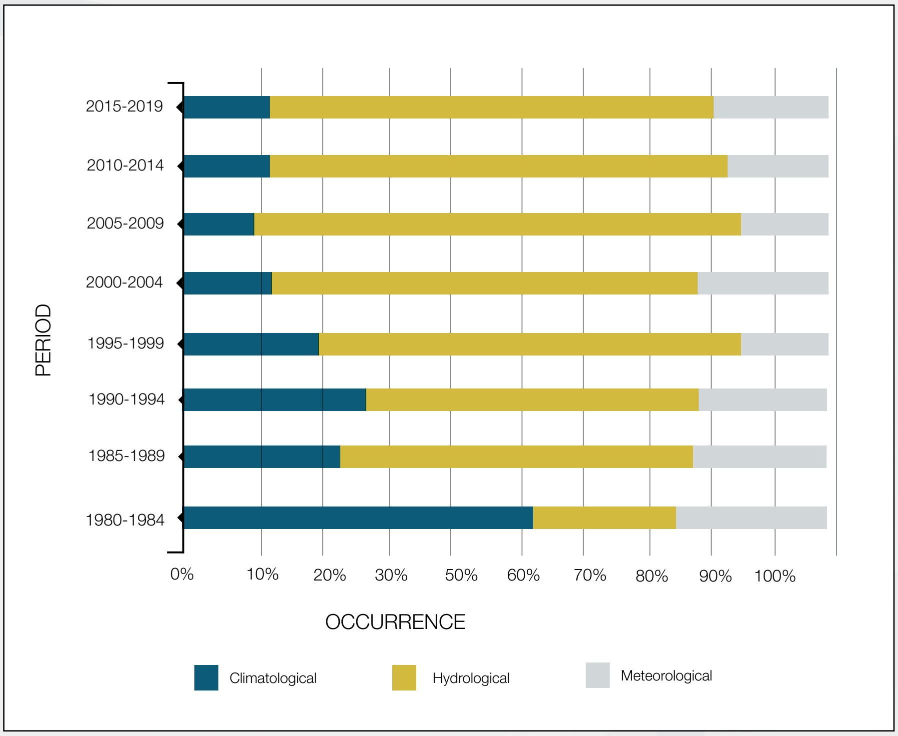
Livestock farmers in southern Africa suffered losses due to starvation and to early culling of herds

30% decrease
in grain production across the region;

2.2.1 The current situation

The current climatic situation in Africa is assessed by analyzing data on extreme climatological (drought and extreme temperature), hydrological (floods) and meteorological (storms) events. Most areas of the African continent lack sufficient observational data to draw conclusions about trends in annual precipitation over the past century[26] and, when available, discrepancies exist between different data sets[27]. The results of changes in temperature and precipitation, due to climate change, often manifest in extreme climate events. As a result, in this study, the occurrences of these extreme events are used as a measure of how climate has changed over time.

Figure 2.3. Percentage of climatological, hydrological and meteorological events recorded in Africa in 5-year periods from 1980 to 2019



SOURCE: EM-DAT, CRED/UCLouvain, Brussels, Belgium www.emdat.be (D. Guha-Sapir)

Based on data in the Emergency Events Database (EM-DAT)[28], the number of climatological, hydrological, and meteorological events, over the last 40 years, was analysed. The EM-DAT database was developed to serve the purposes of humanitarian action at national and international levels. The goal of the initiative is to rationalize decision making for disaster preparedness, as well as to provide an objective base for vulnerability assessments and priority setting. The database includes information on the date, type, and location of events, as well as the number of people affected (deaths, injuries, homelessness).

Figure 2.3 presents the occurrence of each type of event as a percentage, displayed in 5-year periods. The results show that the percentage of climatological

26 IPCC, 2014: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 688.

27 Nikulin, G., C. Jones, F. Giorgi, G. Asrar, M. Buchner, R. Cerezo-Mota, O.B. Christensen, M. Deque, J. Fernandez, A. Hansler, E. van Meijgaard, P. Samuelsson, M.B. Sylla, and L. Sushama, 2012: Precipitation climatology in an ensemble of CORDEX-Africa regional climate simulations. Journal of Climate, 25(18), 6057- 6078.

28 https://public.emdat.be/

Table 2.1. Climatological, hydrological, and meteorological events from January-December 2020

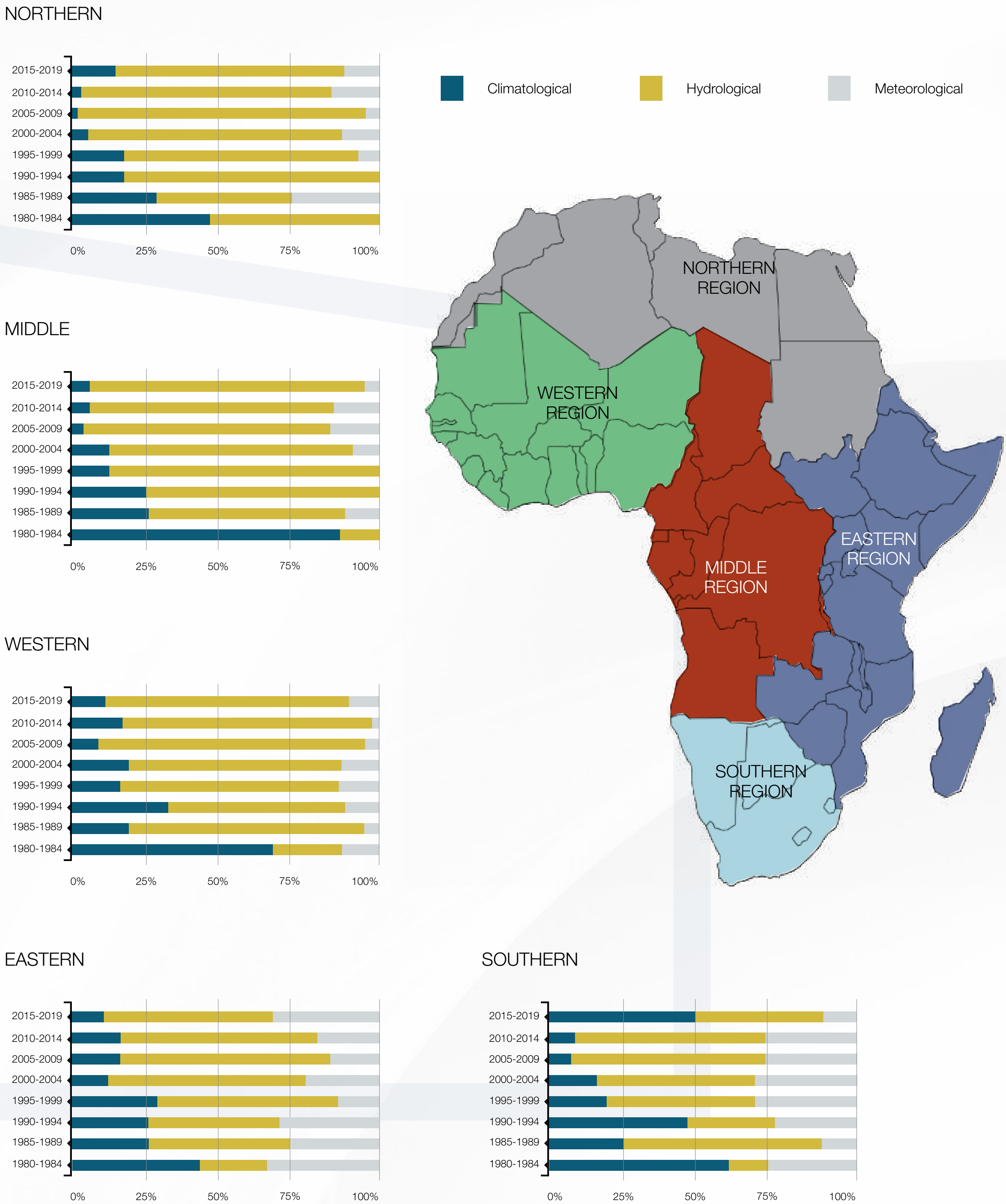
Region	Climatological (DROUGHT + EXTREME TEMPERATURE)	Hydrological (FLOODS)	Meteorological (STORMS)
Northern	0	4	0
Western	4	17	0
Middle	0	12	0
Eastern	1	39	3
Southern	1	2	1
Total	6	74	4

SOURCE OF DATA: EM-DAT https://public.emdat.be/

events dropped from 52% between 1980 and 1984, to about 12% for the most current period (2015-2019). At the same time, hydrological events have increased from 22% in 1980-1984 to 69% in 2015-2019. Meteorological events have remained relatively stable, between 13% and 23%. 3 recent extreme events of importance in Africa are presented in Box 2.2. The numbers of events from January to December 2020 are indicated in Table 2.1. Hydrological events dominated during 2020, as has been the trend since the last half of the 1980s.

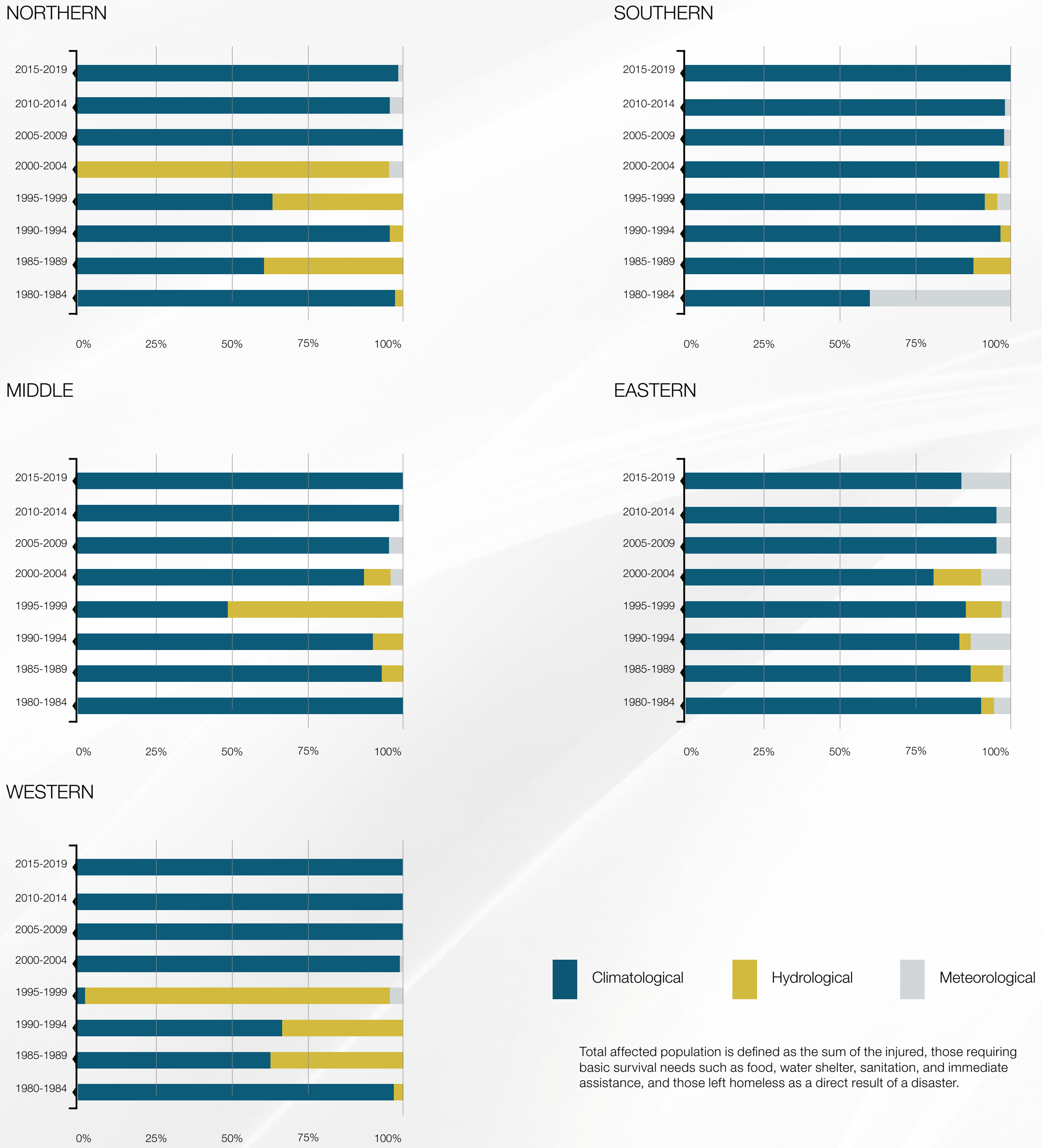
A look at extreme events on a regional basis (Figure 2.4) shows that the occurrence of meteorological events (as a percentage of all extreme events) is relatively consistent in the northern, western, and central regions, with the eastern and southern regions experiencing a greater percentage of these events. The southern region has also experienced a noticeable increase in climatological events in the last 5-year period (2015-2019). All other regions have seen a decrease over time. Overall, hydrological events have increased over time in all regions, and have made up the most important events, percentagewise, in all except the eastern and southern regions, as mentioned.

Figure 2.4. Percentage of climatological , hydrological and meteorological events in 5-year periods from 1980 to 2019 in the 5 regions in Africa



Source of data: EM-DAT https://public.emdat.be/

Figure 2.5. Percentage of total affected populations by climatological (droughts, extreme temperature), hydrological (floods) and meteorological (storms) events in 5-year periods from 1980 to 2019 in the 5 regions in Africa.



Source of data: EM-DAT https://public.emdat.be/

As shown in Figure 2.5, although hydrological events dominate, the human impact is considerably more severe from climatological (droughts and extreme temperature) events. The data shows the percentage of total affected population, by event. Affected population is defined as the sum of the injured, those requiring basic survival needs such as food, water shelter, sanitation, and immediate assistance, and those left homeless as a direct result of an event[29]. The same is true for the number of deaths due to extreme events: between 1980 and 2019, 580,000 million people died as a direct result of drought and extreme temperature events, 20,000 from flooding and 10,000 from storms.

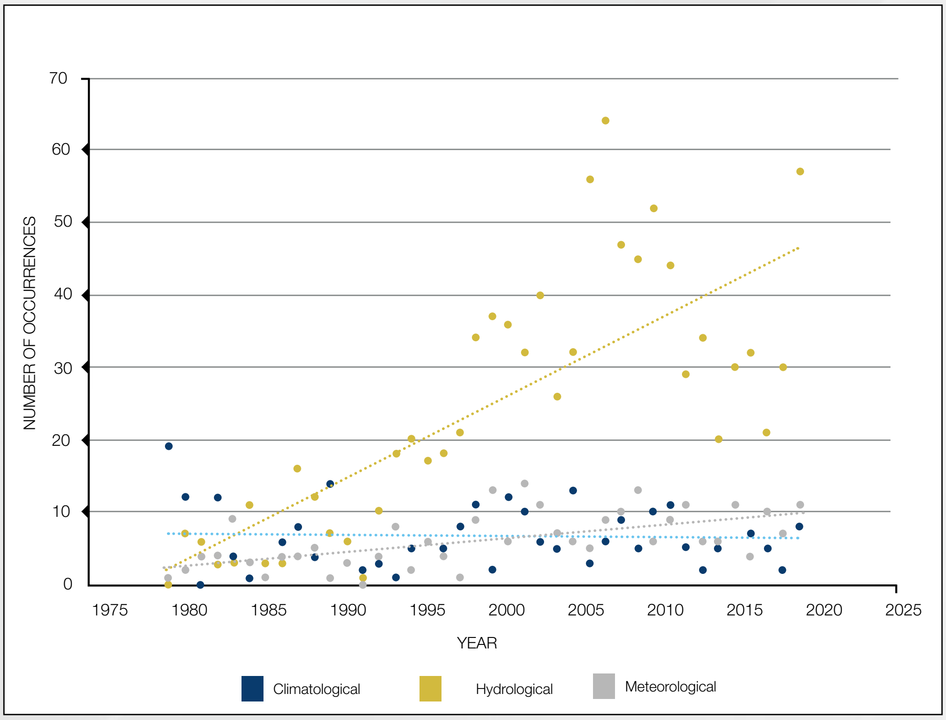
29 Although the EMDAT database does not specify, women and girls are known to suffer disproportionately after natural disasters.

2.2.2 Future climate

The Fifth Assessment Report of the IPCC[30] contained future projections for temperature and precipitation, based on a number of modeling scenarios[31]. Their conclusions included the following:

- Temperatures in Africa are projected to rise faster than the global average increase during the 21st century;
- Over North Africa, both annual minimum and maximum temperatures are likely to increase in the future, with greater increase in minimum temperature;
- Temperature projections over West Africa for the end of the 21st century will range between 3°C and 6°C above the late 20th century baseline;
- Mean land surface warming in Southern Africa is likely to exceed the global mean land surface temperature increase in all seasons;
- A reduction in rainfall over northern Africa is very likely by the end of the 21st century;
- Models indicate the possibility of a wetter core rainfall season with a small delay to the rainy season by the end of the 21st century in West Africa;
- An assessment of model scenarios over eastern Africa suggests that by the end of the 21st century there will be a wetter climate with more intense wet seasons and less severe droughts during October November-December and March-April-May;
- A drying signal is indicated over the climatologically dry southwest of Southern Africa extending northeastward from the desert areas in Namibia and Botswana.

Figure 2.6. Projection of climatological, hydrological, and meteorological events in Africa



source: EM-DAT, CRED/UCLouvain, Brussels, Belgium www.emdat.be (D.Guha-Sapi).

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30 Niang, I., O.C. Ruppel, M.A. Abdrabo, A. Essel, C. Lennard, J. Padgham, and P. Urquhart, 2014: Africa. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1199-1265.

31 It is noted that due to a lack of data and/or differing assumptions between models, there can be a range in the results reported for the same region.

A projection of extreme events, can be deduced from the data presented in Figure 2.6, assuming a continuation of the same trend. The number of hydrological events in Africa is increasing rapidly while the number of meteorological events is also increasing, but at a lower rate. The number of climatological events appear to be constant or even slightly decreasing.

The IPCC results for extreme temperature and rainfall projections also indicate an increase in extreme precipitation events (floods) in the future; however, the confidence level for some of these projections is modest. Some conclusions include:

- Over West Africa there is low to medium confidence in projected changes of heavy precipitation by the end of the 21st century with regional model studies suggesting an increase in the number of extreme rainfall days over West Africa and the Sahel during May and July and more intense and frequent occurrences of extreme rainfall over the Guinea Highlands and Cameroun Mountains;

- A continued warming in the Indian-Pacific warm pool has been shown to contribute to more frequent East African droughts over the past 30 years during the spring and summer seasons, although it is unclear whether these changes are due to anthropogenic influences or multidecadal natural variability. There are projected increases in heavy precipitation over the region, with high certainty along with an increase in the number of extreme wet days by the mid-21st century;

- The southwestern regions of Southern Africa are projected to be at a high risk of severe droughts during the 21st century and beyond. Large uncertainties exist on the projected changes in tropical cyclone landfall from the southwest Indian Ocean. Future precipitation projections show changes in the scale of the rainfall probability distribution, indicating that extremes of both low and high precipitation may become more frequent in the future.

Overall, there are sufficient indications, either through observation or modeling studies, that the future climate in Africa will feature higher temperatures and changes in the amount and timing of precipitation.

2.3 WATER RESOURCES MANAGEMENT AND ADAPTATION TO CLIMATE CHANGE

Managing evolving hydrologies associated with a changing climate will significantly increase the demands on water management. Water stress is already high in many developing countries, particularly those in Africa. Climate change predictions have introduced additional water management issues, with potentially extreme economic, social and political ramifications.

In TBRs, in particular, the implications of increasing water management issues and necessary adaptations to climate change have greater consequences as they affect a number of nations. In particular, new water allocation schemes will need to be negotiated. Although the amount of water available in a river basin may not necessarily change, the distribution and timing of rainfall likely will, which will create new surpluses of water in some regions, while increasing the competition for decreasing resources in others.If surpluses occur, an increase in flood control measures will be necessary in regions that are not currently anticipating this issue. In regions of increasing water scarcity, management to avoid conflicts will be critical. Additionally, maintaining river ecosystems will become a more pressing management issue as guaranteed minimum flows and watershed and environmental protection measures become necessary to preserve the aquatic ecosystems on which lives, and livelihoods depend.

Historically, climate change adaptation has suffered a lack of financing, although the Paris Agreement[32] establishes the requirement to balance adaptation and mitigation finance. Adapting to the impacts of climate change will require between $140 to $300 billion each year by 2030. As of 2016, only $22 billion had been made available[33].

Adapting to the impacts of climate change will require between $140 to $300 billion each year by 2030. As of 2016, only $22 billion had been made available.

32 United Nations Paris Agreement (2015). ADOPTION OF THE PARIS AGREEMENT - Paris Agreement text English (unfccc.int)

33 Barbara K. Buchner, Padraig Oliver, Xueying Wang, Cameron Carswell, Chavi Meattle, and Federico Mazza. 2017. Global Landscape of Climate Finance 2017. Climate Policy Initiative Report.

3 TRANSBOUNDARY WATER RESOURCES IN AFRICA – A RISK ASSESSMENT

As outlined earlier (Chapter 1), TBW resources are a significant feature throughout Africa. TBRs cover 62% of the total area of the continent with 90% of water in Africa found in 63 TBR catchments (Figure 1.2). Furthermore, TBAs underlie 40% of the continent (Figure 1.3), and 33% of the population (381 million) live on such aquifers. However, despite the importance of these vital water supplies in Africa, only 35% of the TBRs and less than 10% of the TBAs in Africa are the object of a TBW agreement.

In this section, characteristics of TBRs and TBAs in Africa, which may facilitate adaptation to climatic changes, are presented, leading to a classification of risk exposure to climate change effects for TBRs and an identification of potential hotspots for TBAs. TBW agreements in Africa are then presented and analysed based on indicators that are considered essential for climate-proofing.

3.1 ASSESSMENT OF TBRS

The aim of this assessment was to analyse the characteristics of TBRs in Africa that increase their susceptibility to the effects of climate change: increases in air and water temperatures, increased variability in water supply and increased frequency and severity of water-related disasters. To do this, an analysis of pertinent TBR indicators was carried out. These indicators were taken from the Global Environment Facility (GEF) Transboundary Waters Assessment Programme (TWAP), which provides a global-scale assessment of water resources, including groundwater, lakes and reservoirs, river basins, large marine ecosystems, and open oceans, to improve knowledge for informed decision-making, to raise awareness, and to foster co-operation among stakeholders[34].

The specific aims of the TWAP River Basins component are: (i) to produce a baseline assessment of global TBRs (and some deltas) to enable the identification of priority issues and hotspots at risk from a number of stressors; and (ii) to establish a sustainable institutional framework to support the baseline and periodic assessment to track changes over time[35].

Table 3.1. Overview of TWAP River Basin Assessment thematic groups and indicators

Thematic Group	Indicators	
	Baseline (2010)	Projected (2030-2050)
Water Quantity	Environmental water stress Human water stress Agricultural water stress	Environmental water stress Human water stress
Water Quality	Nutrient pollution Waste pollution	Nutrient pollution
Ecosystem	Wetland connectivity Ecosystems impact from dams Threat to Fish Extinction rate	Environmental water stress
Governance	Legal framework Hydropolitical tension Enabling environment	Exacerbating factors to hydro-political tension
Socio-economic	Economic dependence on water resources Societal well-being Exposure to floods and droughts	Change in population density

34 http://www.geftwap.org/
35 UNEP-DHI and UNEP (2016). Transboundary River Basins: Status and Trends. United Nations Environment Programme (UNEP), Nairobi.

This is not intended to be a detailed state-of-the-environment evaluation for each of the transboundary basins but, rather, a relative analysis that allows a comparison between basins, based on relative risks. To this end, the assessment is based on categorizing a number of indicators on their risk level, ranging from "very low" to "very high" (from 1 to 5).

The TWAP assessment is intended to be broad in scope. Issues affecting the well-being of humans and ecosystems have been classified into five thematic groups: water quantity, water quality, ecosystem, governance, and socio-economic (Table 3.1). Indicators for each group were selected to establish the "baseline" situation (2010) and formulate projections to 2030 and to 2050. Although it is not possible to predict how each of these groups will develop in the future, indicators that are expected to impact their evolution are identified.

For example, the socio-economic thematic group is represented by the change in population density indicator, which is a key driver for the level of economic dependence, societal well-being and exposure to floods and droughts, based on how these indicators are calculated. Descriptions of indicators are found in Annex 1.

The TWAP assessment is carried out at the basin scale as well as for basin country units (BCUs) which are the portion of each riparian country within a particular basin. A deeper analysis at the level of BCUs enables an understanding of the differences between BCUs lying within a transboundary basin.

Details of the approach and methodology used in the development of the TWAP River Basins Assessment are found in the document published by the United Nations Environment Programme (UNEP)[36].

For this study, the baseline data (2010) were assessed, as follows:

1. For all TBRs in Africa, the risk level (from 1 to 5: "very low" to "very high") for each individual indicator was taken from the TWAP study.

2. Results from the individual indicators were then used to assess the risk level for each thematic group.

   - The indicators were arranged into the thematic groups defined in the TWAP study (see column 1 in Table 3.1). Those TBRs that have a risk level of "high" (4) or "very high" (5) for an indicator, within a thematic group, were highlighted (see Table 3.2).
   - The risk level for each thematic group was determined by counting the number of indicators[37] assessed as high-risk in each group. If the risk level for one or more indicator is "high", then the risk level assigned to a thematic group is "high". The exception is for the ecosystem thematic group: in this case, if there are two or more indicators with a risk level of "high", then the thematic group is assigned a risk level of "high". An additional thematic group, named "Water supply + demand" has been added to the thematic groups defined in the TWAP study. This groups together the "renewable water supply", and "relative water use" indicators.

The results were then analysed to determine those basins that are at greatest risk from climate change effects (see Table 3.5).

The number of thematic groups assessed as having a risk level of "high" are counted for each of the TBRs. TBRs with only one or two thematic groups having a risk level of "high" are considered to be at low risk for climate change effects, those with three or four groups assessed as high-risk are considered to be at moderate risk and those with five or six groups are considered high-risk.

Results for the projected risk (2030/2050) were taken directly from the TWAP study. Although the TWAP supplies data for indicators at the basin level, these are calculated as an average for all countries across a basin. This can lead to anomalies in the results. For example, the TWAP categorizes the Nile River basin as very low-risk for the renewable water supply indicator. However, Egypt's position in the basin is critical, as the Nile waters are the only renewable surface water source in the country, and this BCU is categorized as very high-risk for this indicator, as is Sudan. When the average category score for the BCUs in the basin is calculated, the whole Nile River basin is placed in the very low category. For the purpose of this study, however, the assumption is made that if one or more countries in a basin are categorized as high to very high-risk for an indicator, then the whole basin is categorized accordingly. The rationale is that a BCU that is classified high-risk is likely to affect other BCUs within its basin. Of particular importance when dealing with the effects of climate change and adaptation needs, is that a basin needs to be managed as a whole, considering any "hotspots". In the Nile River basin example, the TWAP basin level analysis means that this river basin would not be categorized as very high-risk for the renewable water supply indicator. However, both Egypt and Sudan are very high-risk for this indicator, and this represents one of the main drivers of political conflict in the basin.

36 UNEP-DHI and UNEP (2016). Transboundary River Basins: Status and Trends. United Nations Environment Programme (UNEP), Nairobi.
37 For this study, the two highest risk TWAP levels (high/very-high) have been amalgamated and presented as one risk level (high).

3.1.1 Evaluation of population, water supply and water demand

The main factors affecting the severity of climate change impacts on TBRs are population growth, water availability or supply, and water use. The TWAP indicators that measure these features are:

- Change in population density: increases in population density will increase the demand for water;
- Renewable water supply: the internal water supplies available to the basin divided by the total population in the basin;
- Relative water use: the mean annual water withdrawals as a proportion of the internal and upstream water supplies available to the basin.

Results for the change in population density are presented in Figure 3.1. For this indicator, the high-risk category represents TBRs that have an increase in population density of over 75% since 2010.

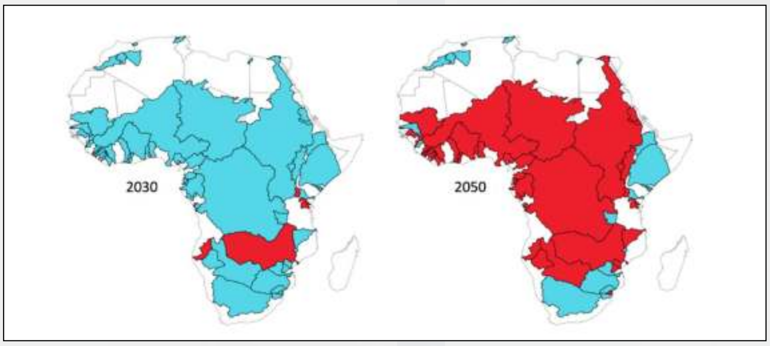
Population growth, together with economic development, is one of the main drivers of water demand and use in river basins and, in some regions, will dictate future water scarcity to an even greater degree than climatic changes[38]. Population change is a practical way of assessing pressures on natural resources.

Key Findings

(Population, Water supply, Water Demand)

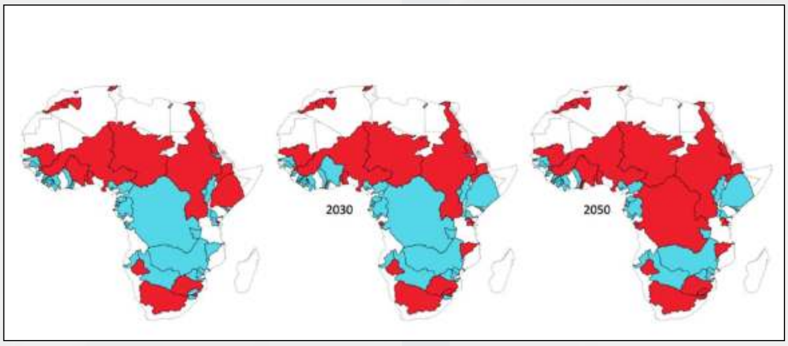
- Population growth is linked to water stress and the need for improved governance. Population growth is a key driver of water use and affects water supply in a basin. Along with climate change and land-cover changes, water systems in TBRs will be increasingly under stress, increasing the importance of good governance.

Figure 3.1. Changes in population density



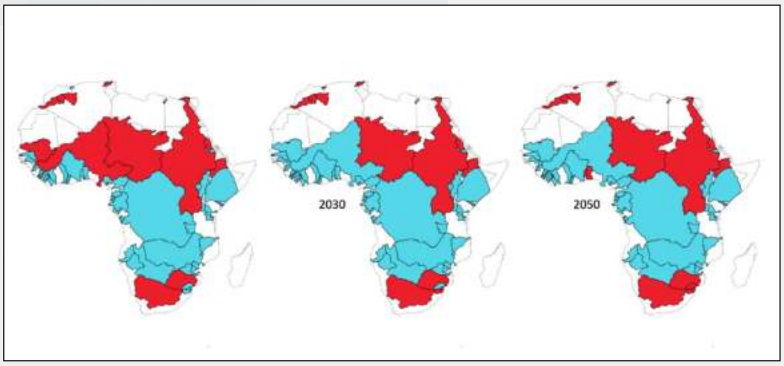
River basins that are categorized as high-risk for this indicator are shown in red; other river basins are in blue
Source data from TWAP.

Figure 3.2. Renewable water supply projections



Source data from TWAP.

Figure 3.3. Relative water demand projections



River basins that are categorized as high-risk for this indicator are shown in red; other river basins are in blue
Source data from TWAP.

38 Vörösmarty C.J., Green P, Salisbury, J and RB Lammers. 2000. Global water resources: Vulnerability from climate change and population growth. Science 239: 284-288.

Table 3.2. Baseline (2010) TBR assessment results for indicators and thematic groups. High-risk is indicated in red.

River basin	Water quantity			Water quality			Ecosystems			Governance			Socio-economic			Water supply + Demand	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Akpa					■		■	■		■		■		■			
Atui	■	■			■					■					■	■	
Awash		■			■		■			■			■	■	■	■	
Baraka		■			■					■			■	■	■	■	
Benito/Ntem					■			■		■	■	■		■			
Bia					■		■	■		■		■					
Buzi					■		■							■			
Cavally					■			■		■		■		■			
Cestos					■			■		■		■		■			
Chiloango					■					■		■	■	■			
Congo/Zaire					■			■	■	■	■	■	■	■			
Corubal					■	■		■				■		■			
Cross					■	■		■	■	■		■		■			
Culevai/Etosha		■			■		■					■		■	■	■	
Daoura	■	■			■		■			■						■	
Dra	■	■			■		■			■						■	
Gambia					■	■		■				■	■	■			
Gash					■	■	■			■					■		
Geba					■	■		■		■		■	■	■			
Great Scarcies					■	■	■	■		■		■		■			
Guir		■			■					■					■	■	
Incomati					■	■	■					■		■	■		
Juba-Shibeli		■			■			■		■			■	■	■	■	
Komoe					■	■	■	■		■		■	■	■			
Kunene					■		■	■				■		■	■		
Lake Chad	■	■	■		■	■	■	■		■	■	■	■	■	■	■	
Lake Natron					■	■		■		■					■		
Lake Turkana					■		■	■		■	■			■	■		
Limpopo	■	■		■	■	■	■				■		■	■	■	■	
Little Scarcies					■	■		■		■		■		■			
Loffa					■			■		■		■		■			
Lotagipi Swamp					■	■	■			■				■	■		
Mana-Morro					■	■		■		■		■		■			
Maputo					■	■	■					■	■	■			
Mbe					■			■		■		■		■			
Medjerda					■		■	■		■			■		■	■	
Moa					■			■		■		■		■			
Mono		■			■	■		■		■	■			■			
Niger	■	■			■	■	■	■		■		■		■		■	
Nile	■	■	■		■	■	■	■	■	■	■	■		■	■	■	
Nyanga					■					■		■	■	■			
Ogooue					■			■		■	■	■	■	■			
Okavango					■							■		■	■		
Orange		■			■		■	■					■	■	■	■	
Oued Bon Naima				■	■					■							
Oueme		■			■		■	■		■		■	■	■	■	■	
Pangani					■	■		■		■				■	■		
Pungwe					■									■			
Ruvuma					■	■		■						■			
Sabi					■	■	■				■			■	■		
Sanaga					■	■		■		■	■	■		■			
Sassandra					■			■		■		■		■			
Senegal		■			■	■		■				■	■	■	■	■	
St.John (Africa)					■			■		■		■		■			
St. Paul					■			■		■		■		■			
Tafna	■	■	■	■	■					■					■	■	
Tano					■	■		■		■		■					
Thukela				■	■	■	■				■						
Umba		■			■		■			■				■	■	■	
Umbeluzi		■			■	■	■	■				■		■	■	■	
Utambozi					■			■		■		■		■			
Volta		■			■	■	■	■				■	■	■		■	
Zambezi					■	■	■	■	■			■	■	■	■		

INDICATORS: 1 - Environmental water stress; 2 - Human water stress; 3 - Agricultural water stress; 4 - Nutrient pollution; 5 - Wastewater pollution; 6 - Wetland disconnectivity; 7 - Ecosystem impacts from dams; 8 - Threat to fish; 9 - Extinction risk; 10 - Legal framework; 11- Hydropolitical tension; 12 - Enabling environment; 13 - Economic dependence on water resources; 14 - Societal well-being; 15 - Exposure to floods and droughts; 16 - Renewable water supply; 17 - Relative water use.

Table 3.3. Projected TBR assessment results (for 2030/2050). High-risk is indicated in red.

River basin	Environmental water stress		Human water stress		Nutrient pollution		Projected hydro-political tension	Renewable water supply		Renewable water use		Change in population density	
	2030	2050	2030	2050	2030	2050		2030	2050	2030	2050	2030	2050
Akpa							■						■
Atui	■	■	■	■	■	■	■	■	■				■
Awash	■	■	■	■			■	■	■	■	■		■
Baraka	■	■	■	■	■	■		■	■	■	■		■
Benito/Ntem							■						■
Bia			■	■				■	■				■
Buzi													■
Cavally													■
Cestos													■
Chiloango			■	■				■	■				■
Congo/Zaire	■	■		■			■		■			■	■
Corubal													■
Cross						■	■						■
Culevai/Etosha			■	■				■	■				■
Daoura	■	■	■	■	■	■		■	■	■	■		
Dra	■	■	■	■	■	■		■	■	■	■		
Gambia	■	■				■							■
Gash	■	■		■			■		■				■
Geba		■				■							■
Great Scarcies													■
Guir	■	■	■	■	■	■		■	■	■	■		
Incomati			■	■	■	■	■	■	■		■		■
Juba-Shibeli	■	■					■						■
Komoe	■												■
Kunene												■	■
Lake Chad	■	■	■	■			■	■	■	■	■	■	■
Lake Natron	■	■			■	■	■					■	■
Lake Turkana	■	■			■	■	■					■	■
Limpopo	■	■	■	■	■	■	■	■	■	■	■		■
Little Scarcies													■
Loffa													■
Lotagipi Swamp	■	■				■	■						■
Mana-Morro													■
Maputo			■	■	■	■			■	■	■		
Mbe													■
Medjerda	■	■	■	■	■	■		■	■	■	■		
Moa													■
Mono			■	■	■	■	■	■	■		■		■
Niger	■	■	■	■			■	■	■			■	■
Nile	■	■	■	■			■	■	■	■	■	■	■
Nyanga													■
Ogooue							■						■
Okavango	■	■					■					■	■
Orange	■	■	■	■	■	■		■	■	■	■		
Oued Bon Naima					■	■							
Oueme			■	■	■	■		■	■		■		■
Pangani	■	■	■	■	■	■	■	■	■			■	■
Pungwe							■	■					■
Ruvuma			■	■			■		■			■	■
Sabi	■	■			■	■	■						■
Sanaga							■						■
Sassandra													■
Senegal	■	■	■	■			■	■	■				■
St.John (Africa)													■
St. Paul													■
Tafna	■	■	■	■	■	■		■	■	■	■		
Tano				■					■				■
Thukela					■	■	■						
Umba	■	■	■	■		■	■	■	■			■	■
Umbeluzi			■	■				■	■	■	■		■
Utamboni													■
Volta	■	■		■					■				■
Zambezi	■	■											■

Key Findings

(water quantity)

- Human and environmental water stress are current problems with more TBRs expected to suffer high risks of both.
- Agricultural water stress is currently low in African TBRs, but this is expected to increase in line with growing populations.
- Human water stress needs to be addressed in order to alleviate future environ-mental and agricultural stress. Action is needed to alleviate human water stress in TBRs that are currently at risk for water quality issues.
- Climate change and increased water consumption needed by growing populations will likely increase water quantity stress in the future, especially in arid regions.
- Key aggravators for human water stress are physical water scarcity and high water demand.

Figure 3.1 shows that between the baseline case and 2030, the population densities in 5 basins (Kunene, Lake Natron, Pangani, Umba and Zambezi) are expected to increase by more than 75%. By 2050, 47 of the 63 basins in Africa will have increased population densities, with three of these basins (Pangani, Umba, Kunene) projected to increase by over 200% between 2010 and 2050[39].

Changes in the renewable water supply are presented in Figure 3.2. Renewable water supply is directly affected by population growth, since the internal water supply in a basin will not increase at the same rate, or may decrease, over time. Analysis of the data shows that, there are currently 20 river basins in the high-risk category implying that there is less than 1000 m^3/person/year available, which is considered water scarcity according to the Falkenmark index[40]. In a number of these basins the availability is less than 500 m^3/person/year which is considered absolute water scarcity. Basins classified as high-risk are found in all regions of Africa, except for the central region. The situation is not expected to change considerably by 2030; however, by 2050, eight more basins are expected to fall into the high-risk category.

Changes in relative water use are presented in Figure 3.3. Relative water use is directly affected by the internal water supply in a basin. Analysis of the data shows that the number of TBRs categorized as high-risk for relative water demand will increase modestly (12 currently, 13 in 2030, 16 in 2050). These basins are generally found in the same regions as those that are categorized high-risk for renewable water supply.

3.1.2 Evaluation of TWAP groups and indicators

Table 3.2 and Table 3.3 show those river basins that are classified as high-risk for each indicator within the five thematic groups defined in the TWAP.

3.1.2.1 Water quantity assessment

In the TWAP, water quantity is considered from the perspective of water stress: environmental, human, and agricultural. The TWAP indicators used in the evaluation of water quantity are described in Annex 1.

These consider changes to both water demand (ie: socio-economic changes and climatic changes) and to water supply (affected by climate change), which increase the pressures in TBRs, along with the complexity of managing the basin resources.

As discussed in Chapter 2, climate change alters water supply, through changes in the hydrologic cycle, and increases water demand, through changes in crop water requirements and human and ecological needs, leading to greater challenges in the management and development of water resources in TBRs in many regions of Africa.

Results of the analysis of the TWAP indicators for water quantity risk (baseline, 2030 and 2050) are shown in Figure 3.4 as well as Table 3.2 and Table 3.3. Of the 63 basins, 21 (or 30%) currently show signs of one or more types of water quantity stress: 9 (14%) show signs of environmental water stress, 21 (33%) show signs of human water stress and only 4 (6%) have high agricultural water stress. Of these, 5 TBRs have both environmental and human water stress and 4 have high risk in all of the indicators. By 2030, it is expected that the number of basins experiencing water quantity stress of some kind will rise to 37 (59%), with approximately the same number of basins facing environmental water stress as human water stress and 16 of the 37 basins facing both types of water stress.

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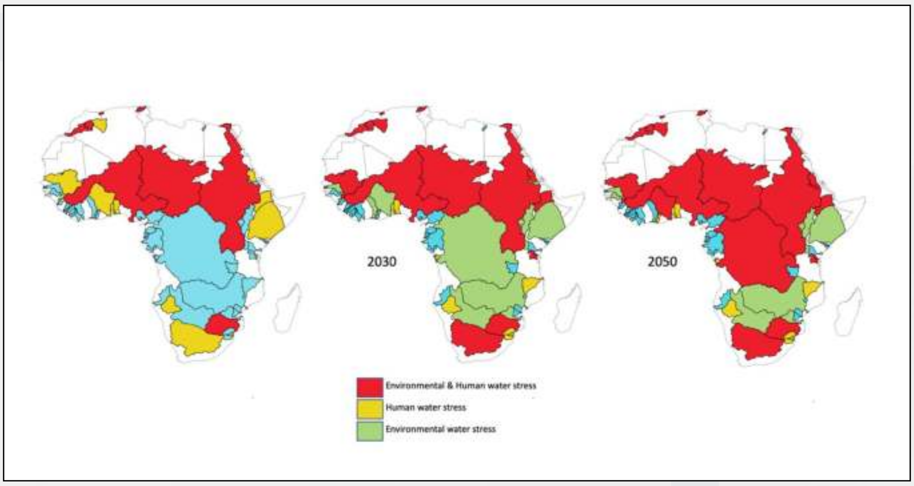
39 UNEP-DHI and UNEP (2016). Transboundary River Basins: Status and Trends. United Nations Environment Programme (UNEP), Nairobi.

40 Falkenmark, M., J. Lundquist and C. Widstrand (1989), "Macro-scale water scarcity requires micro-scale approaches: Aspects of vulnerability in semi-arid development", Natural Resources Forum, Vol. 13, No. 4, pp. 258-267

In 2050, the number of TBRs experiencing one or more types of water quantity stress is not expected to increase significantly (+1). The number of TBRs experiencing human water stress will rise slightly (+4) compared to 2030 and those at high risk of environmental water stress are expected to remain the same. In this projection, 19 basins will face both types of water stress.

These results follow the same trend for changes in population density (Figure 3.1) which shows that 5 basins will experience higher population density by 2030, which increases to 47 basins by 2050. Renewable water supply (Figure 3.2) also shows an increase in the number of basins at high risk, rising from the current situation to 2030 and then to 2050. Both indicators have a direct effect on water quantity stress.

Figure 3.4. Basin projections for environmental and human stress risk



TBRs with low and medium risk are shown in blue
Source data from TWAP.

Agricultural water stress is not included in these results, as it is currently low in TBRs in Africa. The TWAP provides data for the 2010 baseline for agricultural water stress, but no future projections are included. Between the current situation and 2050, an increasing number of basins will suffer both environmental and human water stress, from the current 8 basins to 15 in 2030 and 18 in 2050.

3.1.2.2 Water quality assessment

Deteriorating water quality is an increasing threat to human and environmental health world-wide. In this section, two indicators that are a measure of water quality in TBRs in Africa are analysed: nutrient pollution and wastewater pollution. Nutrient over-enrichment from nitrogen and phosphorus increases the risk of eutrophication which poses a major threat to environmental and human health through algal blooms, decreases in dissolved oxygen, and increases in toxins which make water and some fish and shellfish unsafe for human consumption. These effects can impact tourism and lead to loss of livelihoods in the basin. Nutrients are introduced into the environment through runoff from agriculture (the largest contributor of nitrogen into rivers) through fertilizer use and livestock wastes, while agriculture and sewage are both significant sources of phosphorus pollutants[41]. Pathogens in untreated human waste can also contribute to nutrient over-enrichment.

Nutrient pollution

Nutrient pollution is a growing problem in several TBRs in Africa. The current and projected nutrient pollution risk are shown in Figure 3.5. Under current conditions, there are 5 TBRs considered at risk of nutrient pollution. This number increases to 18 by 2030 and 23 by 2050. The basins at high risk are listed in Table 3.2 and Table 3.3. Given that water use for irrigation in Africa is relatively low, it is expected that there are currently few basins with high nutrient pollution. This may change in the future with increasing agricultural production and a growth in irrigation projects to support increases in population.

Wastewater pollution

Untreated wastewater, from human activity, impacts water quality, human health, and ecosystems. Increased urbanization, often without adequate sanitation services and the regulatory support to control

41 Seitzinger, S. P., et al. (2010), Global river nutrient export: A scenario analysis of past and future trends, Global Biogeochem. Cycles, 24, GB0A08, doi:10.1029/2009GB003587

Key Findings

(Water quality)

- Water quality risks are expected to increase along with increased water demand due to population growth, as well as through increased urbanization and agriculture.
- Mitigation measures are needed in all TBRs in order to reduce the risk. Improvements in wastewater treatment may help to reduce risks to both nutrient and wastewater pollution, while nutrient management in agriculture will help to reduce nutrient pollution, particularly as irrigated agriculture increases. Both strategies are likely to be increasingly important in the future as the population rises.
- Climate change adaptation will be necessary for water quality risk. In the case of decreasing water supply, either due to decreasing input or to increased evaporation due to increased temperatures, pollution may be magnified. In-creasing water input may help by diluting pollutants, but the possibility of increased flooding will mitigate this effect.
- Few African TBRs are currently facing serious nutrient pollution risks as fertilizer use and irrigation, in general, remain low.
- All TBRs in Africa are considered to be at high to very high-risk from wastewater pollution and are, thus, classified as high for overall water quality risk.

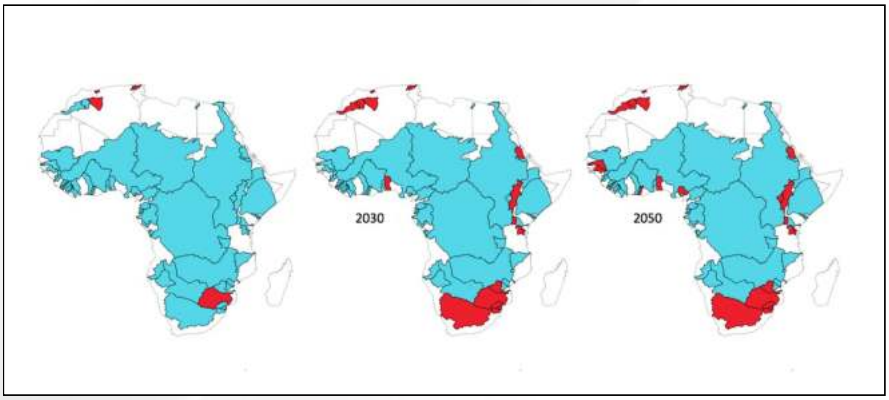
pollution, means that untreated wastewater is a significant problem in many countries and regions of the world[42]. The TWAP wastewater pollution indicator measures the risks of pathogens in TBRs and identifies basins in which action to improve wastewater treatment is needed to reduce impacts on vulnerable communities.

The results for this indicator show that all basins in Africa are currently classified as high-risk. Even in basins with low population densities and abundant water resources, such as the Congo River basin, inadequate wastewater treatment in urban areas of these basins may have a downstream effect[43]. These results can be interpreted as being localized risks around urban centers in the TBRs and attention should be paid to those areas in which rapid urbanization is taking place.

3.1.2.3 Ecosystem assessment

Ecosystems contain species and habitats which humans use to build livelihoods and enhance their well-being. Governing these ecosystems is imperative to ensure their sustainable use, so that they continue to support human needs, while conserving their integrity and health. Key aspects are covered in the four TWAP indicators making up the ecosystem thematic group: wetland disconnectivity, ecosystem impacts from dams, threat to fish and, extinction rate.

Figure 3.5. TBRs in Africa with high-risk for nutrient pollution. River basins that are categorized as high-risk for this indicator are shown in red; other river basins are in blue.



SOURCE DATA FROM TWAP.

42 UNEP (2010). Sick Water? The central role of waste-water management in sustainable development: A Rapid Response Assessment. United Nations Environment Programme, UNHABITAT, GRID-Arendal.

43 UNEP-DHI and UNEP (2016). Transboundary River Basins: Status and Trends. United Nations Environment Programme (UNEP), Nairobi.

Key Findings

(ecosystem)

- Tailored solutions are needed to address risks of species extinction. It is important to identify hotspots in transboundary rivers (for example in TDAs). Conservation strategies should focus on ecological importance and not necessarily scale.
- Wetland disconnectivity risk is important in African TBRs. Wetlands provide a service as a habitat for wildlife and provide functions such as nutrient cycling and climate change adaptation and need to be protected.

Wetland disconnectivity

The TWAP defines wetland disconnectivity as "the measure of the threat imposed by severing the natural physical and biological connections between river channels and their floodplains"[44] which can disrupt natural flow patterns and disturb local flood protection, water storage, habitat, nutrient processing, and natural water purification. It is a measure of the proportion of existing wetlands that were occupied by dense cropland or urban areas in 2010. In these areas human activity is the primary driver which has impeded the hydrological and biological connection between rivers and wetlands[45].

A number of African TBRs (about 44%) have at least one riparian country at risk of functional loss of wetland services, due to human modification of the landscape and natural flow regimes.

Ecosystem impacts from dams

Dam construction and the operation of reservoirs have significant effects on aquatic ecosystems and biodiversity through river fragmentation and flow disruption. The density of dams in a region, particularly medium and large dams, can disrupt ecosystems by acting as barriers to the movement of water and aquatic organisms. A recent count of large dams in Africa puts the number in sub-Saharan Africa at 980, with 589 of these in South Africa[46]. The TWAP database indicates that 46% (29 of 63) of TBRs in Africa are at high or very high-risk to ecosystem impacts from dams. This will only increase in coming years as a number of dams are planned over the continent.

Threat to fish

The main factors threatening inland fisheries are the loss of habitat, environmental degradation, fishing pressure, and the introduction of non-native species. The threat to fish indicator in the TWAP is composed of two sub-indicators which address the pressure of fishing and the introduction of non-native species.

In Africa, fishing pressure is reported to be high in one or more riparian countries in 65% of the TBRs; however, no high-risk rating from non-invasive species is indicated.

Extinction rate

Freshwater ecosystems are extremely rich in biodiversity, containing one-third of all vertebrates[47]. Population growth and socio-economic development have led to increasing pressures on these ecosystems[48], leading to a higher extinction risk in freshwater species than in terrestrial ecosystems[49]. Freshwater ecosystem species and their habitats underpin the functioning and provision of important goods and services, and freshwater species are being lost at a high rate, making it imperative that the drivers of these losses should be holistically addressed on a basin scale. The three largest African river basins (Congo, Nile, and Zambezi) have the highest risk for extinction. In particular, the Great Lakes region of the Nile River basin and Lake Malawi and the lower Zambezi are at high risk, reflecting the high levels of endemism and the threat to fish in these areas[50].

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3.1.2.4 Governance assessment

An assessment reveals that more than 70% of African TBRs are categorized as high-risk, indicating that a limited number of TBR agreements are guided by international legal principles.

The TWAP governance assessment reviews institutional capacity, management instruments and hydro-political tensions stemming from basin development. It considers complementary scales and components of water governance. The indicators assessed the legal framework, hydro-political tension, and the enabling environment. The legal framework indicator maps the presence of key international legal principles in transboundary treaties (equitable and reasonable utilization; not causing significant harm; environmental protection; cooperation and information exchange; notification, consultation, or negotiation; and consultation and peaceful settlement of disputes) to determine the extent to which the legal framework of the basin is guided by these principles. The hydro-political tension indicator analyses the formal provisions in place in TBWs, to reduce tensions arising from the construction of water infrastructure, which is often a source of dispute between countries (for example, the Grand Ethiopian Renaissance Dam in the Nile River basin), as well as other factors that can exacerbate tensions stemming from the development of TBRs. The indicator assessing the enabling environment for water resources management (WRM) on a country basis, acknowledges that the strengths and weaknesses of governance will have implications for water resources in the whole basin. This indicator considers issues such as policy, planning and legal framework, governance and institutional frameworks, and management instruments.

Legal framework

This indicator establishes that good governance of a TBR is guided by the legal agreements in place which provide a strong framework for managing the shared resources. An assessment reveals that more than 70% of African TBRs are categorized as high-risk, indicating that a limited number of TBR agreements are guided by international legal principles. Additionally, very few or none of the riparian states in these basins have ratified any of the global water conventions such as the Convention on the Protection and Use of Transboundary Watercourses and International Lakes (the United Nations Economic Commission for Europe's (UNECE) Water Convention) and the United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses.

Hydro-political tension

This indicator maps the risk of potential hydro-political tension that exists when basins are not equipped to deal with transboundary disputes associated mainly with the development of new water infrastructure. The indicator estimates the level of formal institutional capacity, expressed as the presence or absence of relevant treaty provisions and river basin organizations

Key Findings

(Governance)

- Transboundary agreements require attention. Focus is needed on renegotiating and implementing TBR agreements to incorporate a more integrated and sustainable approach to basin-level management, as well as better governance and development. This will become increasingly important in the face of a changing climate.
- Climate change effects are likely to increase conflict risk. Declining water availability, with increased demand, is likely to exacerbate hydro-political tensions.
- Construction of water infrastructure needs to be done in a cooperative context. In river basins in which international water cooperation instruments are absent or limited, formal institutional frameworks for dialogue could be applied to prevent disputes that may stem from the unilateral development of the basin.
- Capacity building within basin countries is required to meet transboundary objectives.
- Enabling environments in TBAs need to be prioritized. This should include basins in which there is an inadequate enabling environment and high-risk across other assessment indicators.

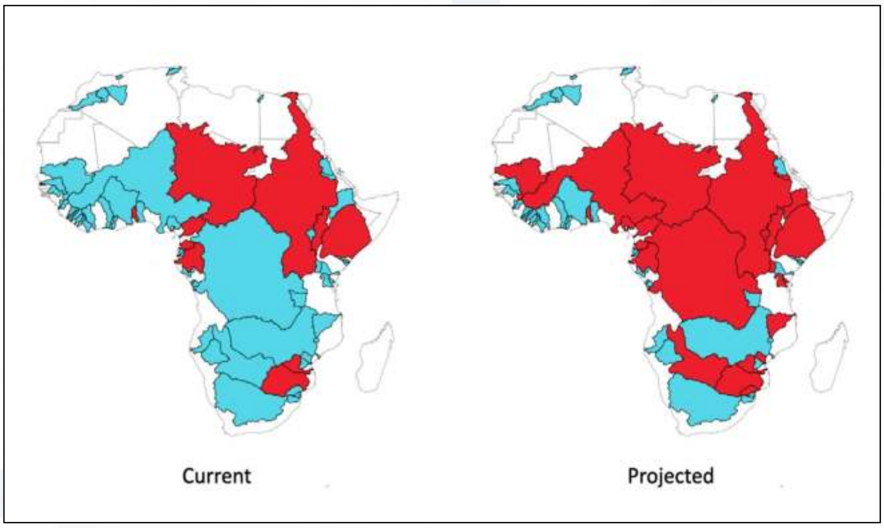
(RBOs), compared with the level of ongoing and planned development of water infrastructure in a basin.

The distribution of new water infrastructure generally happens in areas with high elevation in emerging or developing economies requiring increased hydropower and water regulation to sustain their economic development. Several basins with dam developments exist in Africa, but there is no detectable geographical pattern. Hotspots in the African continent include the Nile River basin (in particular in Ethiopia), where the Grand Ethiopian Renaissance Dam has just been completed, and where there are plans for the construction of several new dams; in the Lake Chad basin, where diverting works are planned or under construction; and in South Sudan, which lacks instruments for transboundary water management.

This indicator considers the institutional capacity for management in the basin, which results from the presence or absence of international treaties and RBO agreements but does not take into account the effective enforcement of formal arrangements.

Analysis of the TWAP assessment reveals that 27 of 63 TBRs in Africa are considered high-risk for current and projected hydro-political tension (Figure 3.6). This indicator considers current factors such as water availability, the presence of international and domestic conflict and economic development in the basin, that may have an impact over the next 10-15 years and therefore can be considered the projected context in 2030. Results indicate the potential for high hydro-political risk throughout the continent. A rise in tension will likely be a result of increased competition over dwindling water supply due to increased demand from increasing populations and the effects of climate change.

Figure 3.6. Current and projected hydro-political tension risk in Africa



River basins that are categorized as high-risk for this indicator are shown in red; other river basins are in blue.
Source data from TWAP.

Key Findings

(socio-economic)

- Larger basins imply greater economic dependence. Larger basins often have higher levels of economic dependence on water resources, as they often include higher populations and larger geographical areas. These larger basins are complex to manage with multiple countries and diversity of priorities, but the need to protect socio-economic well-being is even more critical.
- Benefit sharing is key for basins with high economic activity. Sharing benefits is most critical for basins which have high economic dependence on transboundary waters and high absolute levels of economic activity. The states that share a basin have strong incentive to negotiate benefit-sharing agree-ments and implement integrated river basin management.
- Climate-related risk is associated with economic dependence and low well-being. Basins with high economic dependence, low levels of societal well-being and high exposure to floods and droughts also have the highest climate-related risks.
- Well-being and the governance capacity to address disasters are linked. Where societal well-being is low, governance capacity to address vulnerability to floods and droughts is also likely to be low.

Enabling environment

This indicator considers the level of development and implementation of the enabling environment for water resource management in each riparian country and refers to the policies, plans, legal and institutional frameworks, and management instruments required for effective water resource management, development, and use. A good enabling environment ensures that a framework is in place to enable stakeholder involvement at all levels in water management and considers the needs of all users, including the needs of the environment. A poor enabling environment can hinder effective engagement and representation of stakeholders and inhibit the effective functioning of relevant institutions which together hampers the sustainable management of the basin resources. A high-risk rating for this indicator means that an enabling environment may have been developed but has low levels of implementation, or that the enabling environment has not been developed at all.

Africa has a high number of basins in the high-risk category, particularly in west-central Africa (Congo, Ogooué, Sanaga, Cross, and some other small basins). This indicates that the enabling environment for integrated water resource management (IWRM) in these basins is underdeveloped, or that the levels of implementation are low, either basin-wide or in one or more of the riparian countries. This points to a need for additional efforts to address barriers preventing further implementation, such as supporting policies, institutional frameworks, capacity building, monitoring and information management, and financing for WRM. When assessing the basins in terms of their riparian countries, it was found that there are large discrepancies in the risk levels of enabling environments between individual countries in a basin, which have consequences for basin-level management. For example, the Congo basin includes countries with risk categories ranging from 2 (Tanzania) to 5 (Central African Republic, the Congo, and the Democratic Republic of Congo). This is also found to be the case in the Zambezi, Nile, Niger, and Volta basins. Viewed in the context of basin-wide water quantity, quality and ecosystem indicators, these differences support the need for broad basin-level governance and management to better manage risks to all people and ecosystems, particularly considering the increasing need for adaptation to climate change.

3.1.2.5 Socio-economic assessment

The socio-economic assessment in the TWAP addresses results that focus on three components: the economic dependence on water resources, societal well-being, and exposure to climate-related floods and droughts. The economic dependence on water resources indicator measures the degree to which economies are dependent on the water resources of TBRs or exposed to disruptions from water-related disasters. Societal well-being is a measure of the degree to which basin societies are vulnerable to changes in the quality and quantity of water flowing in the basin and the exposure to floods and droughts indicator measures the degree to which economies and populations are at risk from climate extremes. Shocks and disasters can greatly affect economies by significantly reducing their GDP and slowing development trajectories as well as significantly impacting human well-being.

Economic dependence on water resources

Water withdrawal from rivers, lakes, aquifers, and other reservoirs, for human and production activities, is also imperative for economic growth. For example, freshwater is abstracted for irrigation, industrial and domestic needs. The degree to which a country's economy is concentrated in a TBR is a measure of the level of its dependence on freshwater resources in the basin, and also indicates the risk to economies from disruptions or alterations in the water supply. This indicator can, therefore, shed light on the level of human pressure on water resources as well as the potential effects of changes in climate.

The results of this indicator demonstrate that 20 basins in Africa have at least one basin country with a high level of economic dependence. These basins include the larger basins such as the Nile, Congo, and Zambezi. In general, the larger basins tend to have a higher number of basin countries that are at high-risk. If a basin covers a large proportion of a country's territory, it is more likely that the water resources within that basin will be of greater important in sustaining economic activities.

Societal well-being

Basins with very low levels of societal well-being are more vulnerable to substantial changes to hydrological regimes or climatic shocks because the populations in these basins are generally more directly dependent on water resources for their livelihoods and have fewer assets to enable them to cope with bad years. Any shocks or changes to river basin flows could have significant adverse effects on these populations. The sub-indicators used to calculate this indicator capture a broad range of issues relevant to societal well-being and levels of economic development, including levels of access to improved drinking water supply and decent sanitation, adult literacy, infant mortality rate, and the Gini coefficient (measuring economic inequality). Those basins with low levels in any of these sub-indicators are considered to be more at risk.

Results of the analysis of this indicator reveal that 51 of the 63 transboundary basins in Africa (81%) are categorized as high-risk for societal well-being. Basins in sub-Saharan Africa are at high-risk owing to low levels of economic development which is related to the generally poor governance of TBRs in Africa including limited institutional capacity to manage TBW resources and limited resilience to climate shocks.

> Humans and ecosystems are impacted by floods and droughts through their effects on food security, infrastructure damage, displacement of populations and loss of lives.

Exposure to floods and droughts

This indicator analyses the risks to the populations and economies in transboundary basins, from climate-related disasters, particularly floods and droughts, which cause enormous economic losses and loss of life. Humans and ecosystems are impacted by floods and droughts through their effects on food security, infrastructure damage, displacement of populations and loss of lives. Additionally, efforts to mitigate the impacts of flow variability from climate change through infrastructure development (such as dams, dykes, and canals) can also impact downstream regions of TBRs depending on the hydrology of the system and the type of infrastructure.

Results of the TWAP data assessment indicate that 27 of the 63 TBW systems (43%) have high-risk for exposures to floods and droughts. The risk category for this indicator was again determined by the assessment for each BCU in a basin. If one or more BCU indicated a high-risk of exposure to either flood or drought, then the whole basin is categorized as having high-risk of overall exposure to this risk. Results are shown in Table 3.4. Overall, in the majority of basins, the BCUs indicated more risk exposure to drought. Two basins (Gash and Oueme) show an overall risk of floods and 8 of the 27 basins with high-risk indicate exposure to both floods and droughts. This is not unexpected, given the results of the analysis of extreme events in Africa (Figures 2.3 and 2.4) showing that in the recent past, droughts have been more often experienced than floods, but this has also been changing over time. It should also be noted that the number of people affected by droughts has been greater than the number affected by floods (Figure 2.5).

3.1.3 Selection of at-risk TBRs

Based on the assessments in the previous section, the TBRs were ranked to identify those most at-risk for climate change effects. The ranking was performed for each basin by (i) determining the risk level for each thematic group (water quantity, water quality, ecosystems, governance, and socio-economic) then (ii) identifying the number of thematic groups for which the TBR is at high-risk.

The ranking for each thematic group is based on the importance of each indicator with respect to climate change effects, as follows:

- Water quantity (indicators 1-3): Although this group comprises 3 indicators, the ranking focuses on the results of environmental water stress (indicator 1) and the human water stress (indicator 2). Agricultural water stress (indicator 3) is currently rated as low-risk across Africa, and although it is likely to increase in future, the impact of this demand on water supply will be lower than that of human water stress, which is already highly significant and will increase in line with increased population growth. Environmental water stress is also currently a key issue, and will increase due to climate change and anthropogenic water uses. A basin is ranked as high-risk (shown in red) if one or both of these indicators are rated high-risk as both are important considerations for climate change adaptation.

- Water quality (indicators 4 and 5): Both indicators (nutrient pollution (indicator 4) and wastewater pollution (indicator 5) are used to rank water quality. Any type of current pollution issues (whether nutrient or wastewater) may become amplified in the future due to climate change and the predicted significant increases in population. A basin is considered high-risk for water quality if either of these indicators are categorized as high.

- Ecosystems (indicators 6-9): Extinction risk (indicator 9) is not a large problem in Africa TBRs at this time. The ranking for overall ecosystem risk is calculated based on the other three indicators (wetland disconnectivity (indicator 6), ecosystem impacts from dams (indicator 7), and threat to fish (indicator 8)). Ecosystems can be heavily affected by climate change and any negative impacts will impact the services that they provide. In this risk assessment, any basin that has two or three of these indicators in the category of high or very high are ranked as at risk for ecosystem issues.

- Governance (indicators 10-12): The governance group of indicators are critical to manage any water challenges highlighted in the other thematic groups. The three indicators in this group (legal framework (indicator 10), hydro-political tension (indicator 11), and enabling environment (indicator 12) are all taken into account to determine whether the basins are at high-risk.

- Socio-economic (indicators 13-15): Indicators in the socio-economic thematic group (economic dependence on water resources, societal well-being, and exposure to floods and droughts) assess aspects of the human-environment system in a basin – the economy, human well-being, and disaster risk. Together these assess the degree of dependence of the economy and human populations on water systems and their susceptibility to changes in water quality and quantity. The three indicators are taken into account in the determination of overall risk.

In addition, 2 indicators measure the overall availability of, and pressure on, the resource: renewable water supply and relative water use. Although the change in population density indicator is extremely important, as one of the main drivers of water demand and water supply, most of the countries are categorized as high-risk for this indicator, so it was unnecessary to include this in determining the at-risk basins.

Table 3.4. Analysis of BCU exposure to floods or droughts for TBRs categorized as high-risk for exposure

Basin Name	No. of BCUs in basin with high exposure	High risk for floods	High risk for drought
Atui	2		2
Awash	1		1
Baraka	2	1	2
Culevai/Etosha	1		1
Gash	1	1	
Guir	1		1
Incomati	1	1	1
Juba-Shibeli	2	1	2
Kunene	1		1
Lake Chad	5	1	4
Lake Natron	2		2
Lake Turkana	2		2
Limpopo	4	1	4
Lotagipi Swamp	4		4
Medjerda	1		1
Niger	2	1	1
Nile	3	1	2
Okavango	3		3
Orange	3		3
Oueme	1	1	
Pangani	2		2
Sabi	1		1
Senegal	2		1
Tafna	2		2
Umba	2		2
Umbeluzi	1		1
Zambezi	4	1	3

The next step was to count the number of thematic groups (5 TWAP groups + a group with indicators 16 & 17) that are categorized as high-risk for each TBR. A classification of the at-risk status of each TBR is then determined as follows:

- Low 1 or 2 thematic groups, out of 6, are categorized as high-risk;

- Medium 3 or 4 thematic groups are categorized as high-risk;

- High 5 or 6 thematic groups are categorized as high-risk.

Results are shown in Table 3.5.

Table 3.5. Ranking exposure/vulnerability risk levels of African TBRs to climate change effects

River basin	1&2	4&5	6-8	10-12	13-15	16-17	Exposure/ Vulnerability
Akpa		RED	RED	RED	RED		ORANGE
Atui	RED	RED			RED	RED	ORANGE
Awash	RED	RED			RED	RED	ORANGE
Baraka	RED	RED			RED	RED	ORANGE
Benito/Ntem		RED		RED	RED		ORANGE
Bia		RED	RED	RED			ORANGE
Buzi		RED			RED		GREEN
Cavally		RED		RED	RED		ORANGE
Cestos		RED		RED	RED		ORANGE
Chiloango		RED		RED	RED		ORANGE
Congo/Zaire		RED	RED	RED	RED		ORANGE
Corubal		RED	RED	RED	RED		ORANGE
Cross		RED	RED	RED	RED		ORANGE
Culevai/Etosha	RED	RED		RED	RED	RED	RED
Daoura	RED	RED				RED	ORANGE
Dra	RED	RED				RED	ORANGE
Gambia		RED	RED	RED	RED		ORANGE
Gash		RED	RED		RED		ORANGE
Geba		RED	RED	RED	RED		ORANGE
Great Scarcies		RED	RED	RED	RED		ORANGE
Guir	RED	RED			RED	RED	ORANGE
Incomati		RED	RED	RED	RED		ORANGE
Juba-Shibeli	RED	RED			RED	RED	ORANGE
Komoe		RED	RED	RED	RED		ORANGE
Kunene		RED	RED	RED	RED		ORANGE
Lake Chad	RED	RED	RED	RED	RED	RED	RED
Lake Natron		RED	RED		RED		ORANGE
Lake Turkana		RED	RED		RED		ORANGE
Limpopo	RED	RED	RED		RED	RED	RED
Little Scarcies		RED	RED	RED	RED		ORANGE
Loffa		RED		RED	RED		ORANGE
Lotagipi Swamp		RED			RED		ORANGE
Mana-Morro		RED		RED	RED		ORANGE
Maputo		RED		RED	RED		ORANGE
Mbe		RED		RED	RED		ORANGE
Medjerda	RED	RED	RED		RED	RED	RED
Moa		RED		RED	RED		ORANGE
Mono	RED	RED	RED		RED	RED	RED
Niger	RED	RED	RED	RED	RED	RED	RED
Nile	RED	RED	RED	RED	RED	RED	RED
Nyanga		RED		RED	RED	RED	ORANGE
Ogooue		RED		RED	RED		ORANGE
Okavango		RED		RED	RED		ORANGE
Orange	RED	RED	RED		RED	RED	RED
Oued Bon Naima		RED					GREEN
Oueme	RED	RED	RED	RED	RED	RED	RED
Pangani		RED	RED		RED		ORANGE
Pungwe		RED			RED		GREEN
Ruvuma		RED	RED		RED		ORANGE
Sabi		RED	RED		RED		ORANGE
Sanaga		RED	RED	RED	RED		ORANGE
Sassandra		RED		RED	RED		ORANGE
Senegal	RED	RED	RED	RED	RED	RED	RED
St.John (Africa)		RED		RED	RED		ORANGE
St. Paul		RED		RED	RED		ORANGE
Tafna	RED	RED			RED	RED	ORANGE
Tano		RED	RED	RED			ORANGE
Thukela		RED	RED				GREEN
Umba	RED	RED			RED	RED	ORANGE
Umbeluzi	RED	RED	RED	RED	RED	RED	RED
Utambozi		RED		RED	RED		ORANGE
Volta	RED	RED	RED	RED	RED	RED	RED
Zambezi		RED	RED	RED	RED		ORANGE

INDICATORS: 1 - Environmental water stress; 2 - Human water stress; 4 - Nutrient pollution; 5 - Wastewater pollution; 6 - Wetland disconnectivity; 7 - Ecosystem impacts from dams; 8 - Threat to fish; 10 - Legal framework; 11- Hydropolitical tension; 12 - Enabling environment; 13 - Economic dependence on water resources; 14 - Societal well-being; 15 - Exposure to floods and droughts; 16 - Renewable water supply; 17 - Relative water use.

High-risk for the 5 thematic groups and for the water supply and demand indicators (16 & 17) are indicated in **RED**. In the Exposure/Vulnerability column **GREEN** indicates low overall risk (basins are high-risk for 1 or 2 thematic groups) and **RED** indicates high overall risk (basins are high-risk for 5 or 6 thematic groups). Otherwise, basins are at medium overall risk (basins are high-risk for 3 or 4 thematic groups).

Section 3.4 contains a preliminary analysis of the TBW agreements for the most at-risk TBRs. As indicated in Table 3 5, the TBRs most at-risk are Lake Chad, Limpopo, Niger, Nile, Orange, Senegal Umbeluzi and Volta, all of which have at least one TBW agreement, and Cuvelai/Etosha, Medjerda, Mono and Oueme, which do not have any TBW agreements.

3.2 ASSESSMENT OF TBAS

Groundwater is an important resource in Africa, for both human and development needs including rural livelihoods (agriculture/livestock) and urban water supply[51],[52] . It underlies 40% of the continent and represents 15% of the renewable water resources in Africa. In many regions, groundwater is the only reliable source of water and up to 75% of the population uses groundwater as its main source of drinking water[53], making it of vital importance. This proportion is higher in some arid and semi-arid countries. For example, in Libya, groundwater is the main drinking water source for 95% of the population[54].

In terms of quantity, groundwater is mainly used for irrigation (75%) while domestic water use is at about 20%. Groundwater in rural areas is important for domestic uses. Many large cities on the continent meet a large proportion of their urban demand from wellfields[55]. Not unexpectedly, in drier regions, with low precipitation and low surface water storage opportunities, groundwater use is more developed.

Groundwater development in Africa is driven by three major factors[56]. The first relates to providing better access to safe and clean water supplies, which is part of SDG 6. The second is the need for water to support livestock and small-scale irrigation, which is important for food security, poverty alleviation and livelihoods. The third factor is the variability in temperature and precipitation due to climate change, which will impact on water supply and demand, and groundwater can provide a buffer to improve resilience in times of drought.

Pressure on groundwater resources is growing with an increase in economic development, population growth, and the effects of climate change. It is, therefore, increasingly important to properly manage these resources to ensure sustainability. Currently, 72 TBAs have been identified on mainland Africa[57] (Figure 3.7, Table 3.6). Yet, despite their importance for the future development of the continent, only 11 TBAs have been studied in detail and the level of cooperation on TBAs is still relatively unknown, compared with TBRs. Conflicts of interest, due to the varying capacities of countries to manage these resources, are possible; however, cross-border dialogue and data sharing provide opportunities to improve cooperation and allow better evaluation and more sustainable use of the resource. Nonetheless, only seven TBAs in Africa have specific agreements on joint research, monitoring or governance (Table 3.6).

3.2.1 Risk assessment of TBAs in Africa

The risk assessment of African TBAs is based on data from the TWAP-Groundwater project[58] which assesses 66 of the 72 aquifers in Africa, mostly those that are larger than 5000 km^2 in area. The indicators used in the TWAP project are grouped into four thematic groups: groundwater quantity, groundwater quality, socio-economic, and legal and institutional. Figure 3.8 shows the grouping of indicators and the number of TBAs in Africa that fall into the various risk categories for each indicator.

3.2.1.1 Groundwater quantity indicators

The mean annual recharge rates and groundwater depletion rates for the TBAs in Africa are shown in Figure 3.9. Note that unlike the analysis for TBRs, in which the high and very high-risk levels were treated together as “high”, the TBAs are separated into high and very high, which is identical to the TWAP-Groundwater data. This approach was taken because (1) there was insufficient data for classification in the TWAP; and (2) some indicators, particularly those in the legal and institutional group, have classifications other than very low, low, medium, high and very high.

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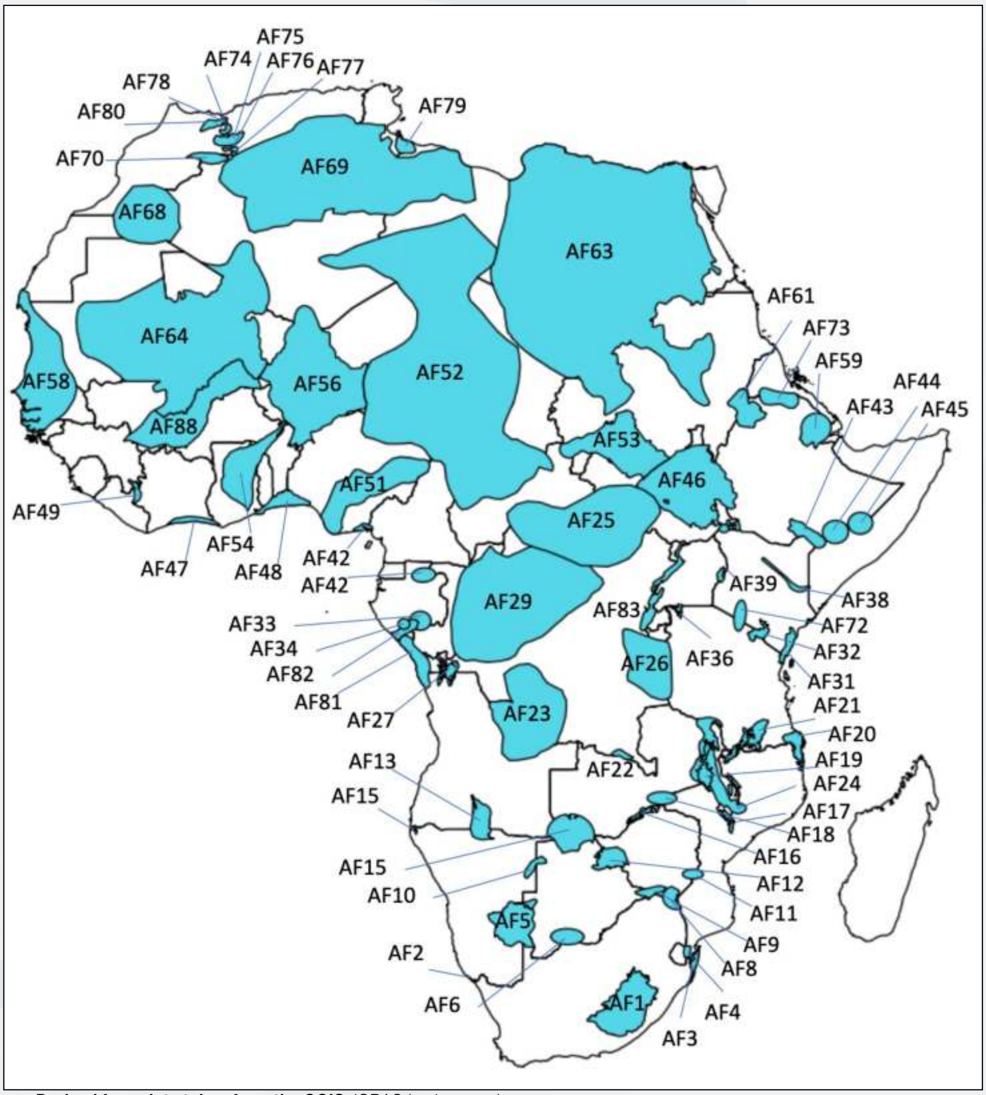
57 https://www.un-igrac.org/resource/transboundary-aquifers-world-map-2015

58 https://apps.geodan.nl/igrac/ggis-viewer/viewer/twap/public/default

The mean annual recharge of groundwater indicates the amount of groundwater that is usable on a sustainable basis. Recharge rates are available for 7 of the TBAs. The Taoudeni Basin aquifer (AF64), the Ain Beni Mathar aquifer (AF75) and the Triffa aquifer (AF80) are all classified as having low recharge (2 – 20 mm/year) and are located in the arid region of northern and western Africa. The Northwest Sahara Aquifer System (NWSAS) (AF69), the Senegalo-Mauretanian Basin aquifer (AF58) and the Nubian Sandstone Aquifer System (NSAS) (AF63) are classified as having very low recharge (<2 mm/year) and are also located in northern and western Africa.

Groundwater depletion rates are measured in mm/year averaged over an aquifer's total area. Overall, the depletion rates are available for four TBAs of which two are classified as high-risk (Taoudeni Basin aquifer (AF64) and Ain Beni Mathar aquifer (AF75)) and one is classified as having very high depletion (Système Aquifère de la Djeffara (AF79)), which also lies in northern Africa.

Figure 3.7. TBAs in Africa



Derived from data taken from the GGIS: IGRAC (un-igrac.org)

Table 3.6. TBAs in Africa. Highlighted TBAs have legal frameworks

ID	Name	Countries
AF1	Karoo Sedimentary Aquifer Karoo Sedimentary Aquifer	Lesotho, South Africa
AF2	Coastal Sedimentary Basin V	South Africa, Namibia South Africa, Namibia
AF3	Coastal Sedimentary Basin VI / Coastal Plain Sedimentary Basin Aquifer	Mozambique, South Africa
AF4	Rhyolite-Breccia Aquifer	South Africa, Swaziland, Mozambique
AF5	Stampriet Aquifer System	Botswana, Namibia, South Africa
AF6	Khakhea/ Bray Dolomite	Botswana, South Africa
AF7	Zeerust / Lobatse / Ramotswa Dolomite Basin Aquifer	Botswana, South Africa
AF8	Limpopo Basin	Mozambique, South Africa, Zimbabwe
AF9	Tuli Karoo Sub-Basin	Botswana, South Africa, Zimbabwe
AF10	Northern Kalahari / Karoo Basin/ Eiseb Graben Aquifer	Botswana, Namibia
AF11	Save Aluvial	Mozambique, Zimbabwe
AF12	Eastern Kalahari Karoo Basin	Botswana, Zimbabwe
AF13	Cuvelai and Ethosa Basin / Ohangwena Aquifer System	Angola, Namibia
AF14	Nata Karoo Sub-basin/ Caprivi deep-seated Aquifer	Angola, Botswana, Namibia, Zambia, Zimbabwe
AF15	Coastal Sedimentary Basin IV	Angola, Namibia
AF16	Medium Zambesi Aquifer	Zambia, Zimbabwe
AF17	AF17 Shire Valley Alluvial Aquifer	Mozambique, Malawi
AF18	Arangua Alluvial	Mozambique, Zambia
AF19	AF19 Sand and Gravel Aquifer	Malawi, Zambia
AF20	Coastal Sedimentary Basin III	Mozambique, Tanzania
AF21	Karoo Sandstone Aquifer	Mozambique, Tanzania
AF22	Kalahari/Katangian Basin/Lualaba	Zambia, Democratic Republic of the Congo
AF23	Coango	Democratic Republic of the Congo, Angola
AF25	Karoo-Carbonate	Central African Republic, Congo, South Sudan
AF26	Tanganyika	Burundi, Democratic Republic of the Congo, Tanzania
AF27	Dolomitic Basin	Angola, Democratic Republic of the Congo, Congo
AF29	Cuvette	Congo, Democratic Republic of the Congo
AF31	Coastal Sedimentary Basin I / Karoo Sedimetary Aquifer	Kenya, Tanzania
AF32	Kilimanjaro Aquifer	Kenya, Tanzania
AF33	AF33	Congo, Gabon
AF34	AF34	Congo, Gabon
AF36	AF36 Kagera Aquifer	Tanzania, Rwanda, Uganda
AF38	AF38 Merti Aquifer	Kenya, Somalia
AF39	AF39 Mount Elgen Aquifer	Uganda,Kenya
AF40	AF40	Congo,Gabon
AF42	Rio DelRey	Nigeria, Cameroon
AF43	Dawa	Ethiopia, Kenya, Somalia
AF44	Jubba	Ethiopia, Somalia
AF45	Shabelle	Ethiopia, Somalia
AF46	Sudd Basin	Ethiopia, Kenya, South Sudan
AF47	Tano Basin	Ghana, Cote d'Ivoire
AF48	Keta / Dahomey/ Cotier Basin Aquifer	Ghana, Togo, Benin, Nigeria
AF49	Cestos - Danane Aquifer	Cote d'Ivoire, Guinea, Liberia
AF51	Aquifer Vallee de la Benoue	Nigeria, Cameroon
AF52	Lake Chad Basin	Chad, Niger, Nigeria, Cameroon, Central African republic, Algeria
AF53	Baggara Basin	Central African Republic, South Sudan, Sudan
AF54	Volta Basin	Benin, Burkina Faso, Ghana, Togo, Niger
AF56	Irhazer-Illuemeden Basin	Algeria, Benin, Mali, Niger, Nigeria
AF58	Senegalo-Mauretanian Basin	Gambia, Guinea-Bissau, Mauritania, Senegal, Western Sahara
AF59	Afar Rift valley/ Afar Triangle Aquifer	Djibouti, Ethiopia
AF61	Gedaref	Ethiopia, Sudan
AF62	Disa	Chad,Sudan
AF63	Nubian Sandstone Aquifer System (NSAS)	Chad, Egypt, Libya, Sudan
AF64	Taoudeni Basin	Algeria, Mali, Mauritania
AF68	Systeme Aquifere de Tindouf	Morocco, Western Sahara, Mauritania, Algeria
AF69	Northwest Sahara Aquifer System (NWSAS)	Algeria, Libya
AF70	Systeme Aquifere d'Errachidia	Morocco, Algeria
AF71	Ncojane Basin	Botswana, Namibia
AF72	Rift Aquifer	Kenya, Tanzania
AF73	Mereb	Ethiopia, Eritrea
AF74	Angad	Morocco, Algeria
AF75	Ain Beni Mathar	Morocco, Algeria
AF76	Chott Tigri-Lahouita	Morocco, Algeria
AF77	Figureuig	Morocco, Algeria
AF78	Jbel El Hamra	Morocco, Algeria
AF79	Systeme Aquifere de la Djeffara	Tunisia, Libya
AF80	Triffa	Morocco, Algeria
AF81	Aquifere Cotier	Angola, Democratic Republic of the Congo, Congo, Gabon
AF82	AF82	Gabon, Congo
AF83	Aquifere du Rift	Democratic Republic of the Congo, South Sudan, Uganda
AF88	Aquifer extension Sud-Est de Taoudeni	Mali, Guinea, Burkina Faso

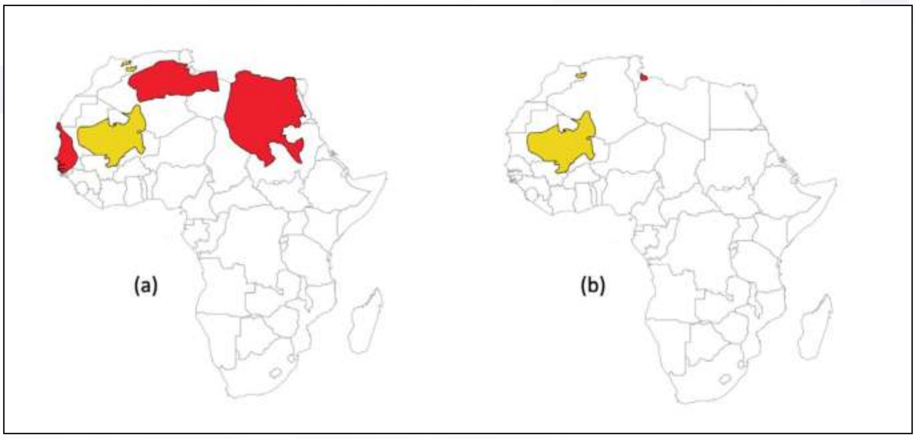
DERIVED FROM DATA TAKEN FROM THE GGIS: https://ggis.un-igrac.org/ "IGRAC (un-igrac.org)"

Figure 3.8. Distribution of African TBAs per category for all TWAP-Groundwater core indicators

Groundwater Quantity Indicators	Recharge (mm/yr)					
	Very High: >300	High: 100-300	Medium: 20-100	Low: 2-20	Very Low: <2	No data
	0	0	1	3	3	59
	Groundwater depletion (mm/yr)					
	Very Low: <2	Low: 2-20	Medium: 20-50	High: 50-100	Very High: >100	No data
	1	0	0	2	1	62
Groundwater Quality Indicators	Natural background quality (% of surface areas with good quality)					
	Very High: >80	High: 60-80	Medium: 40-60	Low:20-40	Very Low: <20	No data
	1	1	0	0	0	64
	Groundwater pollution (%)					
	No pollution identified	Some pollution identified (Not specified)	Low: 0-30	Medium: 30-65	High: >65	No data
	0	0	2	0	0	64
Socio-economic indicators	Population density (inhabitants/km²)					
	Very low: <5	Low:5-10	Medium: 10-50	High: 50-100	Very High: >100	No data
	9	10	22	12	13	0
	Renewable groundwater resources per capita (m³/yr /capita)					
	Very High: >10000	High: 5000-10000	Medium: 1000-5000	Low: 100-1000	Very High: <100	No data
	0	0	1	2	4	59
	Human dependency on groundwater (%)					
	Very Low: <20	Low:20-40	Medium: 40-60	High: 60-80	Very High: <80	No data
	0	0	0	0	2	64
	Groundwater development stress (%)					
	Very Low: <2	Low:2-20	Medium: 20-50	High: 50-100	Very High: <100	No data
	1	0	0	0	5	60
Legal & Institutional Indicators	Transboundary legal framework					
	Agreement with lull scope for TBA management signed by all parties	Agreement with limited scope for TBA management signed by all parties	Legal framework differs between aquifer states	Agreement under preparation or available as an unsigned draft	No agreement exists, nor under preparation	No data
	5	1	1	1	6	52
	Transboundary institutional framework					
	Dedicated transboundary institution fully operational	Dedicated transboundary institution in place, not fully operational	Legal framework differs between aquifer states	National/domestic institution in place, not fully operational	No institution exits for TBA management	No data
	2	3	4	7	1	49

Colors are taken from the TWAP groundwater component information management system (IGRAC (un-igrac.org)). For each indicator, aquifers in the blue and green categories are at low-risk for the dimension described by the indicator. Those in the yellow category indicate medium risk and those in the orange and red categories are at high and very high-risk, respectively.

Figure 3.9. Groundwater recharge (a) and depletion (b). Only those aquifers that are categorized as high (yellow) or very high (red) risk are mapped.



Source data from TWAP - Groundwater.

3.2.1.2 Groundwater quality indicators

Natural background groundwater quality is defined as the percentage of the aquifer area where natural groundwater quality satisfies local drinking water standards. This data is only available for two aquifers (Taoudeni Basin aquifer (AF64) and Senegalo-Mauretanian Basin aquifer (AF58)) and both report high or very high quality.

Groundwater pollution is defined as polluted zones represented as a percentage of the total aquifer area. Data is available for two of the TBAs (Système Aquifère de la Djeffara (AF79) and Senegalo-Mauretanian Basin aquifer (AF58)) and they both report low levels of pollution.

This analysis indicates little concern over groundwater quality in Africa for aquifers where data exists. However, as data is available for so few aquifers, it also indicates that the exploitation of this water source should be investigated in more cases, with more data on all TBAs required.

3.2.1.3 Socio-economic indicators

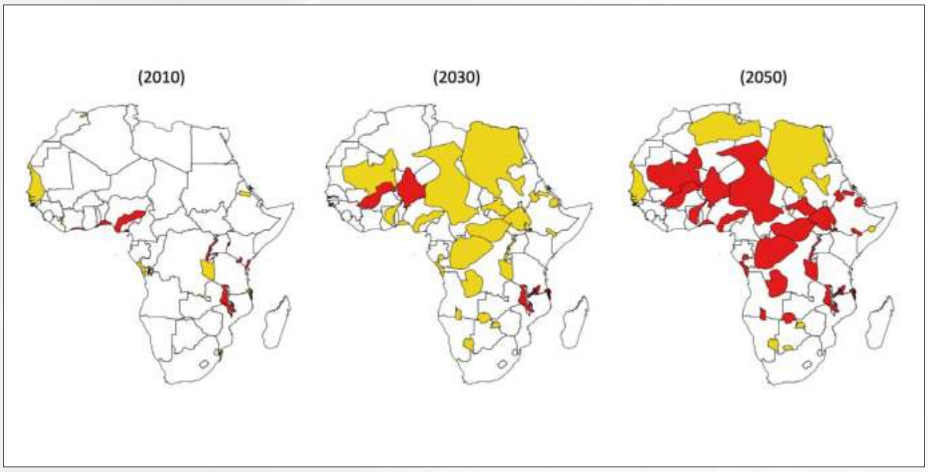
Population density, defined as the number of people living within an aquifer's area, divided by its area, varies from very low (in 9 aquifers) to very high (in 13 aquifers). TBAs with very high population density (2010) are found mostly in western and eastern Africa (Figure 3.10). The change in population density is likely to increase by 30-70% in 68% of the TBAs (of the 34 TBAs in which data was available) and by over 70% in 15% of the TBAs. By 2050, 21% of the TBAs are expected to experience a population growth of 30-70% (compared to 2010) and 74% will see a population growth of over 70%.

Renewable groundwater resources per capita is calculated as groundwater recharge divided by the number of inhabitants situated on the aquifer. This indicator estimates the amount of available groundwater in relation to the number of people that can be support, which is an important factor for considering prospects for the social and economic development of a country or region, particularly if few other water sources are available (see human dependence on groundwater, below). The TWAP includes results for 7 TBAs in Africa, 6 of which have low or very low values (Figure 3.11). Notably, the Ain Beni Mathar aquifer (AF75) and the Système Aquifère de la Djeffara (AF79) have low ratios of groundwater resources per capita (100-1000 m^3/year/capita) and the Senegalo-Mauretanian Basin (AF58), NSAS (AF63), NWSAS (AF69) and Triffa (AF80) aquifers have very low ratios (<100 m^3/year/capita). Based on the Falkenmark indicator47 these regions are already experiencing water scarcity (<1000 m^3/year/capita) or absolute water scarcity (<500 m^3/year/capita). These aquifers are all located in northern or north-western Africa.

Estimated changes by 2030 and 2050, in renewable groundwater resources (per capita) for the 34 TBAs in the TWAP database, are also shown in Figure 3.11. Results indicate that in 20 TBAs in northern, western, and central Africa, a decrease by 2030, by between 30 to 70% of the 2010 value, is estimated. By 2050 all but 7 of the analysed aquifers are expected to have 30-70% decreases in renewable resources per capita.

Human dependence on groundwater, for domestic, agricultural, and industrial water use, is defined as groundwater abstraction as a percentage of total water use. A high dependence on groundwater, in Africa, has been found mainly in the arid climate of northern Africa. The TWAP study indicates a high dependence on groundwater (over 80%) only for the NWSAS (AF69) and Système Aquifère de la Djeffara (AF79), with no data available for the other aquifers.

Figure 3.10. Change in population density over time

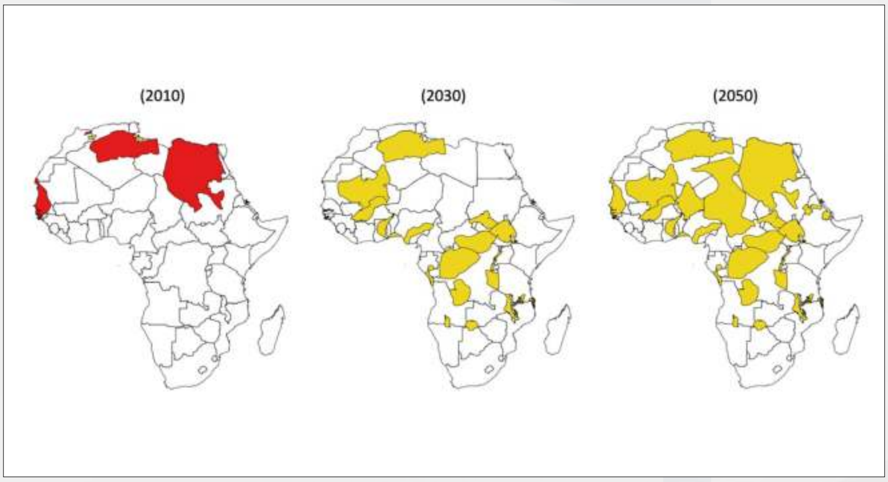


Source data from TWAP - Groundwater.

2010 – current population; 2030 – estimated population in 2030 expressed as a percentage of the 2010 value; 2050 – estimated population in 2050 expressed as a percentage of the 2010 value. Only those aquifers with high (yellow) or very high (red) current values (high = 50-100; very high= >100) or changes (high = 30-70%; very high = >70%) are shown.

Groundwater development stress is defined as annual groundwater abstraction divided by annual recharge. As expected from the earlier results, aquifers with groundwater withdrawals which exceed renewable groundwater resources are in the Sahara and Sahel zones where groundwater recharge to exploited aquifers is extremely low or non-existent. Groundwater development stress is estimated for 6 aquifers, 5 of which have very high development stress (NWSAS (AF69), NSAS (AF63), Triffa (AF80), Senegalo-Mauretanian Basin (AF58) and Système Aquifère de la Djeffara (AF79)) (Figure 3.12). Between 2010 and 2030, 4 additional aquifers are expected to show an increase in groundwater development stress by at least 10%. These include Stampriet Aquifer System (AF5), Mereb (AF73), Keta / Dahomey / Cotier Basin Aquifer (AF48), with Khakhea/Bray Dolomite (AF6) having an increase of over 30%. By 2050, Aquifer Vallee de la Benoue (AF51), Aquifere du Rift (AF83) and Gedaref (AF61) are likely to be added to the list and Mereb (AF73), Khakhea/Bray Dolomite (AF6) and Dahomey / Cotier Basin Aquifer (AF48) are expected to have very high groundwater development stress (more than 30%) compared to the 2010 values.

Figure 3.11. Renewable groundwater resources per capita



Source data from TWAP-Groundwater.

2010 – current situation; 2030 change in renewable groundwater resources per capita over the period 2010 to 2030, expressed as a percentage of the 2010 value; 2050 – change in renewable groundwater resources per capita over the period 2010 to 2050, expressed as a percentage of the 2010 value. Only those aquifers with low or very low current values (low = 100-1000; very low = <100) and high or very high changes (high = -30 to -70%; very high = <70%) are shown.

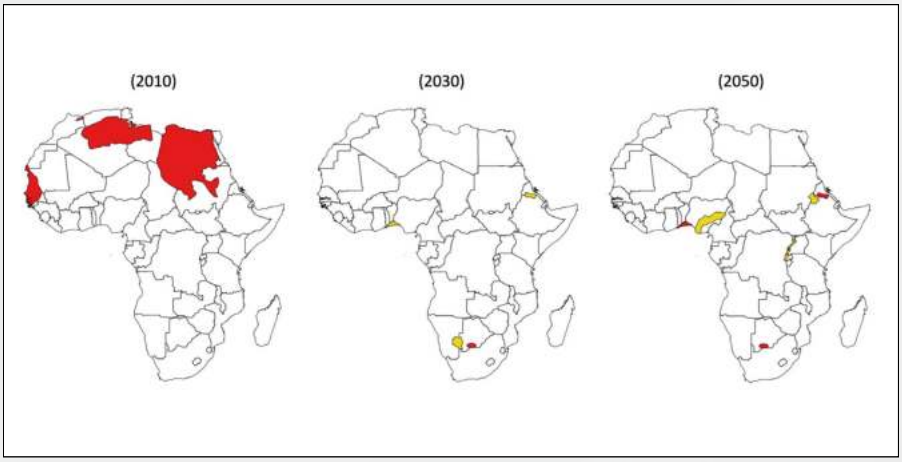
3.2.1.4 Legal and institutional indicators

TBAs are assessed to determine the presence of a legal or institutional framework. Results are presented in Table 3.7. Only 7 TBAs have a legal framework and, of these, 5 have an agreement with full scope for TBA management, signed by all parties. There is one with an agreement with limited scope for TBA management, signed by all parties and another with an agreement under preparation or only available as an unsigned draft. Two of the TBAs with full legal agreements (Coastal Sedimentary Basin III (AF20) and Karoo Sandstone Aquifer (AF21)) also have a fully operational dedicated transboundary institution. These aquifers cover areas in Mozambique and Tanzania in southern and eastern Africa.

The NSAS (AF63) is shared between Egypt, Libya, Chad, and Sudan in north-central Africa (Box 3.1). This TBA has an agreement with full scope for TBA management signed by all parties, and there are national institutions in place, although some are not fully operational. A collaborative study, mainstreaming groundwater considerations into the integrated management of the Nile River Basin, was undertaken to raise the profile of groundwater in the Nile Basin Initiative (NBI) and initiate joint actions on groundwater issues. This could potentially be relevant for the approximately 10 TBAs in, or intersecting, the basin.

The NWSAS (AF69), which is shared between Algeria, Libya, and Tunisia, has an agreement with full scope for TBA management signed by all parties. An institutional arrangement to assess and manage this TBA has also been developed, consisting of a coordinating unit, a steering committee, one institution and research centre for each aquifer country and an ad-hoc scientific committee. A tripartite institutional arrangement was inaugurated in 2008 and continues to function.

Figure 3.12. Groundwater development stress



Source data from TWAP-Groundwater.

2010 – current situation; 2030 change in groundwater development stress over the period 2010 to 2030; 2050 – change groundwater development stress over the period 2010 to 2050. Only those aquifers with high or very high current values (high = 50-100%; very high = >100%) and high or very high changes in percentage points (high = 10 to 30%; very high = >30%) are shown.

The Irhazer-Iullemeden Basin (AF56), located in northern and western Africa, is shared between Algeria, Mali, Niger and Nigeria. This TBA has an agreement on joint policy implementation through a joint legal and institutional consultative mechanism adopted by the aquifer states[59]. It also contains a joint risk mitigation and data sharing policy. The agreement, however, is not yet fully operational within all relevant national institutions and departments dealing with groundwater management.

In southern Africa, the Southern African Development Community (SADC) region is relatively advanced in the management of TBA resources (See Box 3.2). The SADC Protocol on Shared Watercourses (1995) and the Revised Protocol on Shared Watercourses (2000) were instrumental in the addition of groundwater to the programme of activities for which the African Network of Basin Organizations took responsibility in 2008. Some of the RBOs in the SADC region also play a role in transboundary groundwater management. The Orange-Senqu River Commission (ORASECOM) was the first river basin commission in SADC to establish a Groundwater Hydrology Committee (in 2007) to facilitate dialogue between the basin states on TBA management.The ORASECOM Agreement specifically mentions the sharing of hydrogeological data and ORASECOM was one of the parties proposing the piloting of TBA management principles in SADC, focussing on the Stampriet TBA system (AF5)[60].

59 Tujchneider, O., van der Gun, J. (Eds.), 2012. Analysis Report of the Groundwater Working Group – IW Science. The United Nations University.

60 UNESCO-IHP, IGRAC, 2016. Stampriet Transboundary Aquifer System Assessment. Governance of Groundwater Resources in Transboundary Aquifers (GGRETA) – Phase 1. Paris.

Table 3.7. TBAs with legal or institutional frameworks

ID	Name	Legal Framework	Institutional Framework
AF11	Save Aluvial		3
AF16	Medium Zambesi Aquifer		3
AF17	Shire Valley Alluvial Aquifer		3
AF20	Coastal Sedimentary Basin III	1	1
AF21	Karoo Sandstone Aquifer	1	1
AF32	Kilimanjaro Aquifer	2	
AF58	Senegalo-Mauretanian Basin		2
AF63	Nubian Sandstone Aquifer System (NSAS)	1	3
AF64	Taoudeni Basin	3	2
AF69	Northwest Sahara Aquifer System (NWSAS)	1	2
AF70 3	Systeme Aquifere d'Errachidia	1	3
AF75	Ain Beni Mathar	1	3
AF79	Systeme Aquifere de la Djeffara		2

LEGAL FRAMEWORK: 1. Agreement with full scope for TBA management is signed by all parties; 2. Agreement with limited scope for TBA management signed by all parties; 3. Agreement under preparation or available as an unsigned draft.

INSTITUTIONAL FRAMEWORK: 1. Dedicated transboundary institution fully operational; 2. Dedicated transboundary institution in place; not fully operational; 3. National/domestic institution in place, not fully operational.

3.2.2 TBA Hotspots of groundwater stress

An assessment of current, future and potential future hotspots of groundwater stress was carried out in the TWAP assessment, based on the TWAP Renewable Groundwater Resources per Capita, Human Dependency on Groundwater and Groundwater Development Stress indicators (Figure 3.13 and Table 3.8). Results show that most of the current, future, and potential future hotspots occur in northern and western Africa. Southern Africa, although not having any TBAs that are currently considered hotspots, is projected to have five likely hotspots in the future. Overall, a significant increase in the number of hotspots under future conditions is estimated.

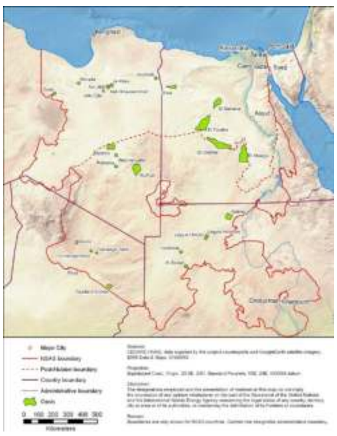
The role of groundwater in expanding the water supply available for irrigation and domestic use, makes it of high importance for several African regions. However, both rapid development and climate change will have major impacts on this water source if it is not adequately assessed and sustainably used and managed. Actions to address the current limited human and institutional capacity to manage TBAs, the lack of hydrogeological knowledge, the absence or rarity of adaptation strategies, and the generally poor understanding of issues, are urgently needed. Groundwater systems respond to human and climatic changes more slowly than surface water systems but can be significantly affected by changes in groundwater recharge and storage, due to alterations in temperature and precipitation, as well as increased demand. Sustainable management may be achieved through practices such as the establishment of monitoring systems, understanding the role of aquifer storage and discharge in supporting ecosystems, and assessing the impact of groundwater abstraction on sustainability. The drivers of sustainable management start with the legal and institutional frameworks that define the rules, processes, and principles of TBA management, development and cooperation, and these need to be created or re-assessed with adaptation to changing conditions in mind.

The role of groundwater in expanding the water supply available for irrigation and domestic use, makes it of high importance for several African regions.

3.3 ASSESSMENT OF TBW AGREEMENTS

Agreements, including conventions, treaties and other institutional arrangements offer important means to equitably and sustainably manage the use and development of TBWs. The 1997 Convention on the Law of the Non-Navigational Uses of Transboundary Watercourses and the 1992 Helsinki Convention on the Protection and Use of Transboundary Watercourses and International Lakes, as well as the United Nations International Law Commission's (UNILC) Draft Articles on the Law of Transboundary Aquifers, encourage TBR and TBA states to establish agreements and joint institutional arrangements on their shared waters (Box 3.3) These agreements offer an important way to enhance cooperation and avoid or resolve disputes between states. They may also provide rules and procedures for allocating water resources and for water quality protection; goals for the sustainable development, management, and protection of the environment; and the institutional framework to apply these rules and procedures. Globally, more than 450 TBW agreements have been signed since 1820. However, about 60% of the TBRs across the world, lack any cooperative agreement. The numbers are even worse for TBAs. In Africa, about 30% of the TBRs (19 of 63) have agreements, while only 7 of the 72 aquifers (about 10%) have legal frameworks. In addition, a number of existing TBR agreements fail to include all riparian countries, or cover the entire basin to which they apply, and many of these are inadequate in enforcement mechanisms, monitoring provisions, and water allocation arrangements to address changing water supply and demand.

Box 3.1. The Nubian Sandstone Aquifer System (AF63) – a history of cooperation



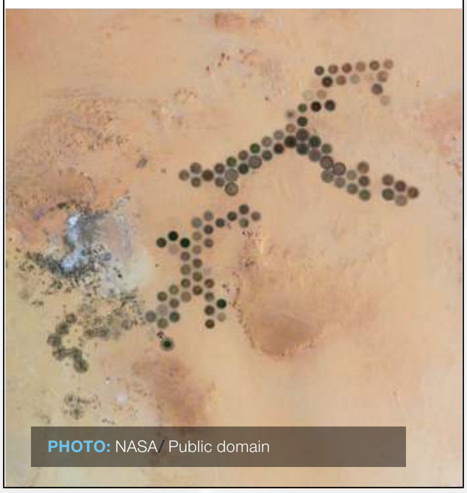


PHOTO: NASA / Public domain

The Nubian Sandstone Aquifer System (NSAS) is one of the largest aquifers in the world, underlying Egypt, Libya, Chad, and Sudan, and covering an area of about 2.5 million km². The overlying area is dominated by desert and an arid to semi-arid climate. Water resources over the last million years, or so, have been controlled by rainy glacial periods and arid interglacial periods. During the rainy periods, significant surface water bodies recharged the aquifer but during the arid periods, which includes present conditions, there has been little or no recharge. Groundwater storage is estimated at about 500,000 km³, only about 3% of which is recoverable, with water quality varying from excellent in the south to saline in the north of Libya.

The NSAS is a major source for both drinking water and irrigation, and its importance to the regional population cannot be overstated. In areas away from the Nile River, the aquifer is the only source of water for irrigation, livestock, industry, and human consumption. As a result, assessing and controlling transboundary impacts between countries is critical to maintain good relationships in the region.

The NSAS States cooperate through agreements made since 1992. The agreement of the Joint Authority for the Study and Development of the NSAS was signed in 1992. The Joint Authority was established in 1989 between Egypt and Libya and launched in 1991. Sudan joined in 1996 and Chad in 1999. The agreement, however, has no provisions for the management of the aquifer or the water stored in it. Advancements in cooperation were made in 2000 with two agreements on monitoring and the updating and sharing of data and information for the sustainable use of the aquifer's resources. The "Regional Action Programme for the Integrated NSAS Management", funded by GEF and implemented by UNDP, IAEA and UNESCO-IHP, furthered cooperation between the NSAS countries by supporting the development of a regional strategy for integrated management of the aquifer, for its equitable long-term use. This project formed the basis for the Regional Strategic Action Plan for the Nubian Sandstone Aquifer System agreement which was signed by the NSAS countries and the Joint Authority in 2013 and binds all parties to agree on actions for the sustainable management of the aquifer.

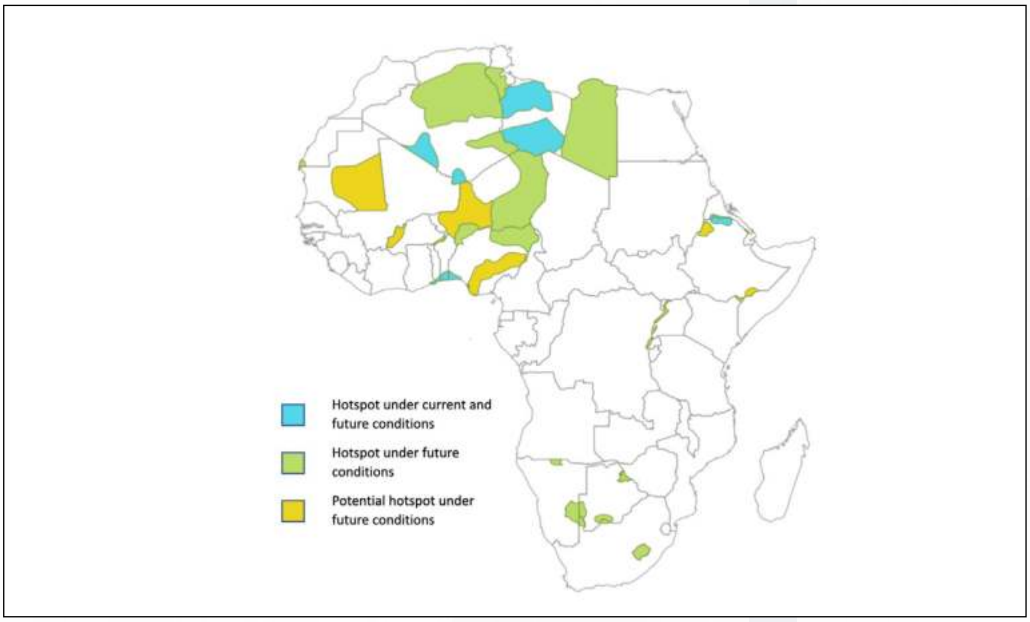
Box 3.2. The Ramotswa TBA (AF7) – recent joint efforts

The Ramotswa TBA is shared between Botswana and South Africa. This aquifer is small, about 300 km² in area, and is intensively used by South Africa. This aquifer is a hotspot in the SADC region and is subject to water insecurity driven by increasing population growth and urbanization in Botswana and from economic water scarcity in South Africa. Additionally, in Botswana, groundwater scarcity is compounded by nitrate and faecal pollution of the aquifer.

A joint project was initiated in 2015 to better understand the aquifer and the issues surrounding its use, with the aim of improving water security and allowing collaborative use. The joint research identified groundwater flow directions and issues of water quality in the aquifer, indicating potential cross-border pollution by nitrates and revealing significant surface water and groundwater interconnections. The data and information generated by this project are shared between the TBA countries and is available through a web-based system to stakeholders. This information formed the basis for the development of a common strategic action plan that identified joint priorities.

The bilateral Joint Permanent Technical Committee functions as an interim forum and precursor for taking forward a formal institutional arrangement for the long-term joint management of the aquifer.

Figure 3.13. Hotspots of groundwater stress



Source data from TWAP-Groundwater.

Table 3.8. Hotspots of groundwater stress (2030 and/or 2050)

	Hotspot under current and future conditions		Hotspot under future conditions		Potential hotspot under future conditions
Aquifer Code	GW dev. stress higher than 20%, dependencyon GW higher than 40%	GW dev. stress higher than 20%, dependency on GW lower than 40%	GW dev. stress higher than 20%, dependency on GW higher than 40%	GW dev. stress higher than 20%, dependency on GW lower than 40%	GW dev. stress lower than 20%, GW recharge per cap. lower than 1000m3/yr and dependency on GW higher than 40%
AF1				X	
AF5			X	X	
AF6			X	X	
AF12			X		
AF13				X	
AF43				X	
AF44					X
AF48	X				
AF51					X
AF52	X		X		
AF54					X
AF56			X		X
AF58				X	
AF59			X		
AF61					X
AF63			X		
AF64					X
AF69	X		X		
AF73	X				
AF83				X	
AF88					X

3.3.1 TBR agreements in Africa

Data from the International Freshwater Treaties Database was assessed to determine the characteristics of treaties governing TBWs in Africa. The database is a searchable store of summaries and full texts of more than 600 international, freshwater-related agreements and represents an on-going effort which is not yet comprehensive, although an update is being developed. The agreements relate to international freshwater resources where the main concern is "water as a scarce or consumable resource, a quantity to be managed, or an ecosystem to be improved or maintained"[61]. Information analysed from international freshwater treaties include water rights and allocation, water pollution, the equitable addressing of water needs, hydropower/reservoir/flood control development, and environmental issues.

In this study, the TBR agreements in Africa are investigated to determine the presence or absence of several mechanisms pertinent to climate-proofing. These mechanisms are described in Table 3.9 where the mechanisms are classified according to a study by Drieschova et al that reviews the application of uncertainty in the design of international water treaties[62]. The classifications of uncertainty proposed are:

- Ignoring uncertainty: For example, a treaty establishing fixed water allocations ignores the obvious possibility that flows will vary over time;

- Open ended strategy: This involves the adoption of risk avoidance tactics by prescribing precautionary policies to limit activities or including flexibility and adaptability in the design of management systems;

- Uncertainty minimization strategy: This strategy attempts to reduce the implications of uncertainty

61 https://transboundarywaters.science.oregonstate.edu/content/data-and-datasets
62 Drieschova A, Fischhendler I, Giordano M. 2011. The role of uncertainties in the design of international water treaties: an historical perspective. Climatic Change 105:387–408

or its core causes. Mechanisms such as data exchange or technology transfer can be adopted to increase the understanding of natural systems, or facilitate the creation of shared hydrologic models to predict future water variability;

- Complete contracts approach: The focus with this approach is to reduce the implications of uncertainty. Provisions may include monitoring frameworks, escape clauses for unexpected conditions, and binding arbitration mechanisms which fully describe feasible actions in as many cases as possible.

Information on the mechanisms assessed, for all agreements for TBRs in Africa, are found in Annex 2.

Box 3.3. Characteristics of global water conventions

SOURCE: UN-Water, 2020: UN-Water Policy Brief on the United Nations global water conventions: Fostering sustainable development and peace. Geneva, Switzerland. (Modified by authors).

1992 Water Convention	1997 Watercourses Convention	Draft Articles on the Law of Transboundary Aquifers
Relevant to transboundary waters – surface or groundwater that marks, crosses or is located on boundaries between two or more states.	Relevant to watercourses – surface water and groundwater that is connected to shared surface water bodies.	Relevant to all aquifers and the groundwater they contain. An attempt to fill the gap left by the Watercourses Convention.
Parties are required to "prevent, control and reduce any transboundary impact".	Parties are obligated to take all appropriate measures to prevent the cause of significant harm, and to preserve the ecosystems of international watercourses.	The international legal regime for transboundary groundwater management is still evolving but the draft articles provide the basis upon which States could develop specific groundwater agreements. The principles of "reasonable and equitable use", and "no significant harm", are embedded, taking into account the unique characteristics of groundwater resources.
Parties must ensure reasonable and equitable use.	Parties are obligated to use international watercourses in a reasonable and equitable manner.	
Parties are required to conclude transboundary agreements and to establish joint oversight bodies.	Parties are encouraged to adopt watercourse agreements, or adapt existing ones, and establish joint mechanisms or commissions.	
Procedures for peaceful dispute settlement are provided.	Procedures for dispute settlement, including third-party fact finding are provided. Cooperation is further fostered with the inclusion of detailed procedures for the notification of planned measures.	
Consists of an institutional framework, which includes a Secretariat and meeting of the parties – this allows the convention to be a dynamic instrument changing to meet the needs of parties.	An institutional framework does not yet exist.	
Three African parties: Chad, Senegal, and Ghana.	Twelve African parties: Benin, Burkina Faso, Chad, Cote d'Ivoire, Ghana, Guinea-Bissau, Morocco, Namibia, Niger, Nigeria, South Africa, Tunisia.	

An analysis of the percentage of TBR agreements in Africa that use known mechanisms is shown in Figure 3.14. This analysis reveals that enforcement, alternative scenarios, prediction modeling, and the inclusion of groundwater are the four mechanisms most lacking in TBR agreements. Joint management, conflict resolution mechanisms, information exchange and amendment mechanisms are the four mechanisms that are most commonly found.

Of the 4 mechanisms that are found most often, 3 are classified as open ended. This is a positive finding, particularly for climate change adaptation, which allows for risk avoidance and may provide flexibility and adaptability in managing water resources. However, the lack of an enforcement mechanism in the TBR agreements reviewed is concerning. In general, there is a positive relationship between the presence of a treaty in a TBR, and cooperation. But a treaty that is not enforced tends to weaken the cooperative benefits. This is particularly important for climate change adaptation. Mechanisms to minimize uncertainty, such as information exchange and variability management will only be effective if enforced. The lack of prediction models and alternative scenarios also weakens agreements for climate change adaptation.

Of the 63 TBRs analyzed in Section 3.1, 45 (about 71%) lack agreements between any constituent riparian countries. The number of agreements for each basin, where at least one agreement exists, is shown in Table 3.10. The table also indicates the number of these agreements that are basin wide. An assessment of the geographic scope of TBR agreements indicates that most of the basin-wide agreements were created to establish join management institutions or RBOs or for the purpose of basin-wide economic development (for example the Agreement on the Establishment of the Zambezi Watercourse Commission or the Convention creating the Niger Basin Authority).

Many of the agreements that are not basin-wide were created for the purposes of managing particular infrastructure (for example: the Agreement between the Republic of Niger and the Republic of Benin relative to the realization of the hydroelectric management of the Dyondyonga site on the Mékrou river; the Agreement between the governments of the Republic of Portugal, the People's Republic of Mozambique and the Republic of South Africa relative to the Cahora Bassa Project; the Exchange of notes constituting an agreement between the government of the United Kingdom of Great Britain and Northern Ireland and the government of Egypt regarding the construction of the Owen Falls Dam in Uganda). There are a number of TBRs that lack any basin-wide agreements, and which are therefore particularly at risk for issues stemming from climate change effects. These include the Nile River basin, which is known for conflicts over water use and development, in particular in the eastern Nile which supplies 85% of the total flow in the basin. It is note-worthy that all of the agreements in the Senegal River basin, and most in the Niger basin, are basin-wide, which highlights, particularly in the Senegal River basin, the vision of cooperative management and development of these basins intended from the outset. Overviews of the legal frameworks in the Nile, Volta and Orange-Senqu river basins are provided in Boxes 3.4, 3.5 and 3.6, respectively.

Figure 3.14. Percentage of the total number of TBR agreements, in Africa, with specified characteristics as defined in the International Freshwater Treaties Database

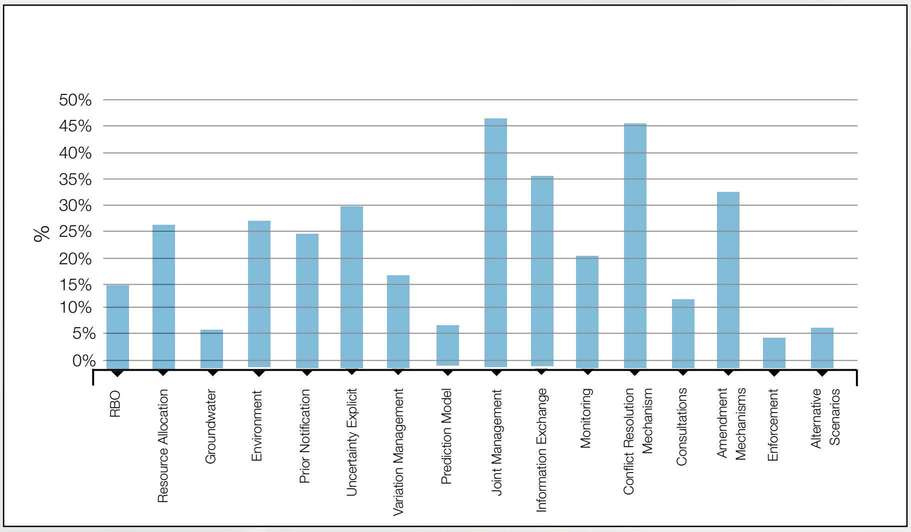


Table 3.9. Description of TBR agreement characteristics as defined in the International Freshwater Treaties Database

Dimension	Description	Classification
RBO	Agreement establishes an RBO: a joint management institution with a broad, general mandate to manage water issues in the entire basin. The presence of an RBO indicates that a treaty is more institutionalized and, as a result, may more easily overcome challenges in the basin. This is especially so if the RBO has conflict resolution, monitoring and/or enforcement mandates. Mainly, though, the presence of an RBO indicates that there is some level of cooperation between riparian states.	Open ended
Allocation	The treaty specifies the allocation of water, hydropower or pollution. The existence of an allocation method, regardless of its nature (such as fixed quantities, percentage of flow or prioritization of uses) provides a starting point in the management of water variability in a basin. However, the allocation of fixed quantities makes the agreement inflexible to the effects of water variability unless other dimensions allow a process for further consultations or amendments of the static provisions.	Ignores uncertainty (fixed-allocation); complete contract (variable allocation); open ended (vague allocation)
Groundwater	An agreement which explicitly mentions groundwater. An agreement that allows for the management and development of all water sources in a basin will help to ensure the sustainability of all water resources in a country, basin, or region.	N/A
Environment	An agreement considers the general environment, water quality or environmental services. In basins that have current pollution problems, agreements that include the consideration of water quality will be more able to adapt to climate effects. Similarly, agreements that protect the environment and ecosystems and their services will be more adaptable to the effects of climate change.	N/A
Prior Notification	Agreement requires signatories to communicate with each other if they want to use additional water resources or construct infrastructure such as dams or diversion channels. Prior notification is another way of allocating water in TBRs and enables flexibility to combat climate change effects on water variability.	Open ended
Uncertainty Explicit	The treaty explicitly mentions some form of uncertainty in its text.	Uncertainty minimization
Variation Management	The document specifically mentions an extreme event (such as flood and/or drought). Variability management stipulations in treaties and agreements allow for the creation of mechanisms to deal with climatic extremes, in particular droughts and floods. The existence of variability management in a treaty implies that parties to the treaty acknowledge the variability of water availability.	Uncertainty minimization
Prediction Model	Treaty develops or mentions available mechanisms for predicting particular aspects about the future, such as the occurrence of floods. The use of prediction models aims to reduce the uncertainty of future development in the basin.	Uncertainty minimization
Joint Management	An agreement which institutes some form of joint management institution or Commission – a specialized institutional body for dealing with the issues stipulated in the treaty and whose scope of action and authority depends upon the treaty. The mandate may be more narrowly defined than an RBO.	Open ended
Information Exchange	Agreement indicates that parties agree to exchange data about important issues such as flows. The basin-wide availability of data and information helps to reduce uncertainty by allowing for more rapid reactions to problems such as water variability or pollution incidents.	Uncertainty minimization
Monitoring	Parties create mechanisms to monitor treaty compliance, to supervise the construction of works, or the financial terms of an agreement, etc. Monitoring mechanisms provide a control over parties to respect their obligations, thereby reinforcing the strength of an agreement.	Complete contract
Conflict Resolution Mechanism	Mechanisms to address disagreements among the signatories. The presence of a conflict resolution mechanism defines the extent to which disputes over the shared resource between riparian countries can be resolved. These are important for minimizing the intensity of grievances within a basin .	Complete contract (legal means); open ended (diplomatic means)
Consultations	Treaty provides for the parties' direct and regular consultations on water issues through diplomatic channels. Consultations do not specify any clear measures to be adopted in order to alleviate uncertainty. Rather, they leave possible solutions open to negotiations between agreement parties.	Open ended
Amendment Mechanism	An amendment of the treaty mentioned in the text is possible. The inclusion of amendment mechanisms makes an agreement more flexible.	Open ended
Enforcement	The document contains provisions concerned with the enforcement of the provisions in the document. Basins with treaties that include enforcement measures generally show higher levels of cooperation.	N/A
Alternative Scenarios	The treaty mentions at least one situation in which a different development can occur and alternative modes of action are stipulated.	Complete contract

Key Findings

(Governance)

- 12 of 63 (19%) TBRs are at high risk for climate change effects
- 94% of TBRs are at medium-high or high risk for climate change effects
- Only 4 of 63 TBrs are at low risk
- 12 of 63 tbrs have at least one basin-wide agreement, which translates to basin-wide cooperation in the development and management of water resources
- Variability management is lacking in many tbr agreements
- Enforcement appears to be lacking in most tbr agreements
- 6 of 71 tbas are currently considered as hotspots for groundwater stress. this number is expected to increase, potentially, to 20 of 71 tbas in the future
- Only 7 of 71 tbas (10%) have agreements

In general, the TBRs without agreements, or those with agreements which fail to extend basin-wide, are those that will have most difficulty adapting to climate change. Regardless of the number of mechanisms which are covered in an agreement, simply the existence of a basin-wide agreement indicates there is some form of cooperation between basin countries, and this can make climate change adaptation easier.

3.3.2 TBA agreements in Africa

3.3.2.1 Legal framework for TBA agreements in the UN- International Groundwater Resources Assessment Centre (IGRAC) assessment

Few TBA agreements exist on record, according to the analysis presented in Section 3.2. As Table 37 shows, only 5 TBAs have legal frameworks. The Coastal Sedimentary Basin III (AF20), Karoo Sandstone Aquifer (AF21), NSAS (AF63), NWSAS (AF69) and Ain Beni Mathar (AF75) have agreements with full scope for TBA management signed by all parties and the Kilimanjaro Aquifer (AF32) has an agreement with limited scope for TBA management signed by all parties. The Taoudeni Aquifer (AF64) has an agreement under preparation or available as an unsigned draft.

- **Coastal Sedimentary Basin III (AF20):** Tanzania reports a signed TBA agreement with full scope and a dedicated transboundary institute, the Ruvuma Basin Water Board, that exists with a full mandate and full capacity. No other information on the mandate of the Ruvuma Basin Water Board for aquifer management has been found.

- **Karoo Sandstone Aquifer (AF21):** There is a ratified transboundary agreement with full scope and a dedicated transboundary institute with full mandate and capacity (the Ruvuma Basin Water Board). The national institutions have a full mandate and capacity. No other information on the mandate of the Ruvuma Basin Water Board has been found.

- **NSAS (AF63):** NSAS agreements include a 1992 agreement that provides for a joint authority of country representatives and two agreements in 2000 that provide rules for monitoring and exchange of groundwater information and for data sharing, signed by Chad, Egypt, Libya, and Sudan. The joint authority has the mandate to collaborate and develop cooperative activities for sustainable and mutually beneficial development of the aquifer, which also includes the monitoring of groundwater withdrawals and levels. Based on the two other agreements, NSAS countries undertook monitoring and the sharing of data and maintenance of a shared regional information system[63].

- **NWSAS (AF69):** The NWSAS is shared by Algeria, Libya and Tunisia and is governed by a tri-lateral "Mécanisme de concertation" (subsequently referred to as the Mechanism). The Mechanism, in 2002, was initially comprised of country focal points and a Coordination Unit headed by a Coordinator. In 2006, a Council of Ministers and a Permanent Technical Committee were added to the initial structure of the Mechanism and National Committees replaced the original National Focal Points, through a joint Declaration of the Water Ministers of the three countries. The mandate of the Mechanism is to manage and monitor the aquifer; promote and conduct joint studies; and report on the state of the aquifer. In 2015, a protocol was drafted on the legal basis of the member countries' commitment to cooperation[63] although no information on this protocol was found.

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63 Burchi S. 2018. Legal frameworks for the governance of international transboundary aquifers: Pre- and post-ISARM experience. Journal of Hydrology: Regional Studies 20: 15-20

Table 3.10. Number of basin wide TBR agreements

TBR	No. of agreements in total	No. of basin-wide agreements
Congo/Zaire	4	1
Gambia	6	0
Gash	2	0
Geba-Corubal	1	0
Incomati	6	4
Kunene	3	3
Lake Chad	3	3
Limpopo	5	0
Maputo	3	0
Moa	1	1
Niger	14	9
Nile	24	0
Okavango	2	1
Orange	9	1
Senegal	11	11
Umbeluzi	2	1
Volta	1	1
Zambezi	13	1

TBR Agreements

- Few TBRs are currently facing serious nutrient pollution risks as fertilizer use and irrigation, in general, is low.
- All TBRs in Africa are considered to be at high to very high-risk from wastewater pollution and thus, classified as high for overall water quality.

- **Ain Beni Mathar (AF75):** No information on the legal framework for this aquifer has been discovered.
- **Kilimanjaro Aquifer (AF32):** Currently, extraction from the Kilimanjaro Aquifer is low and occurs primarily on the Tanzanian side, in the Pangani River Basin. From the information provided by Tanzania, there is a signed memorandum of understanding (MOU) with limited scope in place, although no further information has been found. A dedicated transboundary institute, the Pangani Basin Water Board exists with a full mandate and full capacity. The Pangani Basin Water Office administers the Tanzanian part of Pangani River Basin and its mandated activities include supervision of both surface water and groundwater resources, but only in an advisory role.
- **Taoudeni Aquifer (AF64):** According to Mali there is an agreement under preparation or available as an unsigned draft and a dedicated transboundary institution that is fully operational. No details on this agreement have been published, however, it is possible that the agreement mentioned refers to the MOU discussed in the next section (3.3.2.8). There is some evidence that AF64 and AF56 are considered as one aquifer (Iullemeden and Taoudeni/Tanezrouft Aquifer Systems), as mentioned by the Observatoire du Sahara et Sahel[64].

64 http://prog.oss-online.org/en/joint-and-integrated-water-resources-management-iullemeden-taoudeni-tanezrouft-aquifer-systems-and

Box 3.4. Nile River basin - Legal framework

A basin-wide legal framework exists for the Nile River basin. Currently, three types of legal instruments – bilateral treaties, a multilateral agreement establishing a framework for cooperation, and a tripartite agreement on a declaration of principles, govern the use and allocation of Nile waters. These are:

BILATERAL TREATIES

→ 1902 Agreement: This is a bilateral treaty between Great Britain (on behalf of Sudan) and Ethiopia to delineate the boundary between Ethiopia and Sudan. It also contains a provision related to the use of waters in the Nile, in which Ethiopia undertook to not construct or allow the construction of an infrastructure across the Blue Nile, Lake Tana or the Sobat, that would stop the flow of water into the Nile, except with the agreement of the Government of the Sudan.

→ 1929 Nile Agreement: This is a treaty between Egypt and Britain (representing Sudan) that recognizes the historical and natural rights of Egypt to the Nile waters and gave Egypt the power to veto any construction projects along the Nile River and its tributaries. The treaty also allocated a volumetric quantity of water to Egypt (48 billion cubic metres (BCM)) and Sudan (4 BCM). In defining these amounts, the treaty also defined the "established rights" of the two states within the overall basin.

→ 1959 Agreement: This agreement, between Egypt and Sudan, allocated the net benefit generated from the High Aswan Dam. This amounted to the bulk of the Nile's waters (55.5 BCM of the 84 BCM total flow) going to Egypt and 18.5 BCM to Sudan. 10 BCM was estimated for evaporation from the High Aswan Dam. The rights of no other basin states were recognized.

FRAMEWORK FOR COOPERATION

→ The Nile Basin Cooperative Framework Agreement (CFA): The 1995 CFA was an attempt to prepare a basin-wide legal and institutional framework to regulate interstate utilization and management of the Nile River resources. Negotiations involved all basin states except Eritrea. Parallel negotiations (the Nile Basin Initiative (NBI)) focused on development in the basin, at which the same basin countries as the CFA participated. During negotiations of the CFA, the main controversy was over the 1902, 1929 and 1959 Agreement contents. Upstream countries believed that the CFA would produce an inclusive agreement to supersede the previous agreements. Egypt and Sudan, on the other hand, insisted that the CFA explicitly recognize the earlier treaties, which they expected would continue to be binding. The agreement was opened for signature in 2010. Six upstream states have signed and 3 have ratified the agreement. Six ratifications are required to enter into force so, as it exists, the CFA neither binds Egypt and Sudan nor reallocates the waters of the basin.

TRIPARTITE AGREEMENT ON THE USE AND ALLOCATION OF NILE WATERS

→ Agreement of Declaration of Principles (DOP): Upon signing the CFA, Ethiopia started construction of the Grand Ethiopian Renaissance Dam (GERD). Initially, Egypt and Sudan opposed the dam, claiming that it would significantly affect their interest and violate the rules that regulate water allocation in the basin. Then Sudan, considering the many benefits it would also receive from the dam, changed its position. Eventually, the three states signed a (DOP), concerning the GERD in 2015. This agreement can be considered as the principal legal regime governing the Blue Nile sub-basin and 85% of the total Nile River flow.

Box 3.5. Volta River basin - Legal framework

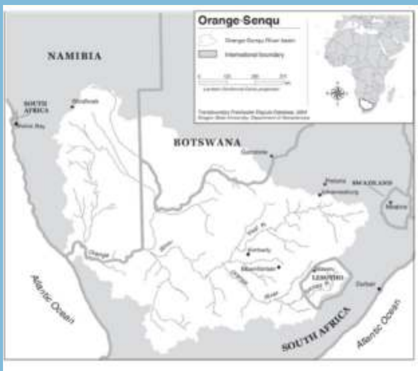
The main agreement driving the management and development of the Volta River basin is the Convention on the status of the Volta River and the Establishment of the Volta Basin Authority (2007), signed by Benin, Burkina Faso, Côte D'Ivoire, Ghana, Mali, and Togo, and covering important issues such as the joint management of the basin, water quality, navigation and economic development.

THE VOLTA BASIN AUTHORITY (VBA) AGREEMENT INCLUDES:

- Establishment of an RBO with a broad, general mandate to manage water issues across the entire basin;
  Conflict resolution mechanisms covering any disputes, including those arising from the interpretation or enforcement of the Convention, and the handling of cases where an amicable settlement cannot be found;
- Principles for the rational and sustainable utilization of the water resources of the Volta Basin, including the notification of planned activities that could have negative effects elsewhere, as well as the related consultations and negotiations; the regular exchange of data and information among the State Parties; and the protection and conservation of ecosystems;
- Amendment mechanisms indicating that the VBA Convention may be amended by a request from any of the parties and any approved amendment will enter into force under the conditions set out in the Convention;
- Groundwater linked to the Volta River basin system is within the jurisdiction of the Authority, along with all tributaries and sub-tributaries, reservoirs and lakes, wetlands, aquatic and land ecosystems, and estuaries linked to the basin.

Future successful development and management of the watercourse in the Volta River basin depends on the implementation of the obligations defined in the Convention and the capacity and stability of the VBA to successfully carry out its mandate. Some of the main concerns include a continuing lack of financial contributions from member states, staffing and establishment of the structures of the RBO, and high turnover in political leadership. Additionally, climate change issues and adaptation need to come to the forefront as cooperative plans for water use development and implementation procedures, such as for data and information integration and sharing and notification procedures, are established.

Box 3.6 Orange-Senqu River basin - Legal framework



The four riparian states (Namibia, Botswana, South Africa, and Lesotho) in the Orange-Senqu basin have established eight bilateral agreements and one basin-wide treaty. Four of these are particularly relevant to the management of the basin: the 1986 treaty providing the framework for the Lesotho Highlands Water Project (LHWP) and the establishment of a Joint Permanent Technical Commission (JPTC), the 1992 agreement establishing the Vioolsdrift and Noordoewer Joint Irrigation Scheme (VNJIS), the 1992 agreement creating the Permanent Water Commission (PWC), and the 2000 agreement establishing the basin-wide Orange-Senqu River Commission (ORASECOM). The LHWP treaty and the VNJIS agreement focus on the planning, operation and maintenance of joint projects in the basin. The agreements establishing the PWC and ORASECOM create the joint institutions mandated to advise parties on the development and utilization of shared waters.

- Determination of the long-term safe yield of the water resources in the river system;
- Equitable and reasonable utilization of the water resources in the basin to support sustainable development;
- The investigation and study (separately or jointly with riparian states) of the development of the river system, including the construction, operation, and maintenance of any water works;
- Water resources pollution control including management of aquatic weeds in the river system;
- The development of contingency plans and measures for responding to emergency situations or harmful conditions resulting from droughts and floods or from human conduct such as industrial accidents;
- Regular exchange of information and consultation on the possible effects of planned measures;
- The standardization of processes for collecting, processing and disseminating data or information on all aspects of the river system;
- Measures for dispute settlement between agreement parties.

3.3.2.2 Other legal and institutional frameworks for TBAs in Africa

- **Iullemeden Aquifer System (AF56):** In 2009, the three states sharing the Iullemeden Aquifer System (Niger, Nigeria, and Mali), signed a "Memorandum of Understanding relating to the Setting up of a Consultative Mechanism for the management of the Iullemeden Aquifer System". This MOU is not listed in the UN-IGRAC system, but is the first comprehensive treaty for the management of a TBA.

- **The objectives of this MOU are:** to promote integrated management of the aquifer and cooperation in communication and information; to jointly identify risks to which the water resources are exposed; to facilitate the joint management of risks; and to enable further sustainable development of the resources. The MOU defines 14 functions of the consultative mechanism, including providing opinions on polices and projects, the coordination of programmes, providing recommendations to harmonize legislation, and the settling of disputes. The parties also commit to take into consideration a range of general principles relating to equitable and reasonable utilization, public participation, nondetrimental use, precautionary measures, and the polluter pays and user pays principles. General obligations are set out, emphasizing sustainability and the protection of the aquifer, as well as planned measures which detail procedural obligations, including obligations to exchange data and information, and a detailed notification procedure. Finally, provision is made for the settling of disputes.

- **Groundwater management in bilateral and multilateral surface water treaties:** Some bilateral treaties address groundwater as well as surface water. These include the Convention on the Sustainable Development of Lake Tanganyika; the Tripartite Interim Agreement between the Republic of Mozambique, the Republic of South Africa and the Kingdom of Swaziland for Co-operation on the Protection and Sustainable Utilisation of the Water Resources of the Incomati and Maputo Watercourses; and the Protocol for Sustainable Development of Lake Victoria Basin. The legal framework on the Orange-Senqu River basin also has a high degree of focus on groundwater but, generally, these agreements are based upon the geographic limits of surface water management, primarily the river basin, and rarely include a holistic consideration of groundwater.

- **Strategies for regional economic communities:** SADC, in particular, has a dedicated Regional Strategic Action Plan for IWRM which explicitly addresses TBA management though transboundary diagnostic analysis (TDA) and strategic action plans as part of a wider groundwater management programme in the region. Work to identify "troublesome" TBAs was carried out to focus investigatory resources on those aquifers that were in need of cooperative management[65]. Several outputs on TBAs in the SADC groundwater management programme have been produced, including a region-wide map of groundwater drought risk[66].

65 Davies J., Robins N.S., Farr J., Sorensen J., Beetlestone P., Cobbing J.E. 2012. Identifying transboundary aquifers in need of international resource management in the SADC Region of southern Africa. TBA Paper, June 2012.

66 Villholth KG, Tøttrup C, Stendel M, Maherry A (2013) Integrated mapping of groundwater drought risk in the Southern African Development Community (SADC) region. Hydrogeol J. doi:10.1007/s10040-013-0968-1

4

CLIMATE-PROOFING TBW AGREEMENTS

Climate-proofing strategies

- Propositional water allocation
- Allocation exemptions
- Minimum allocation
- Dispute settlement

Future pressures on water resources, such as population growth, economic growth, and climate change, will pose a wide variety of challenges for freshwater management. Added to the numerous political entities and actors in TBRs and TBAs, the sustainable management of shared water resources will be particularly challenging, in order to prevent disputes that are likely to increase with growing pressures.

In this chapter, several case studies are presented which highlight some examples of international TBW agreements that have already have climate-proofing mechanisms incorporated. These case studies, along with international best practices on building climate-proofed TBW agreements, will be summarized to create a comprehensive list of mechanisms and strategies for climate-proofing TBW agreements.

4.1 CASE STUDIES

4.1.1 Strategies responding to drought conditions – Treaty for the Utilization of the Waters of the Colorado and Tijuana Rivers and of the Rio Grande

The United States and Mexico share a 1,954-mile border, from California in the west to Texas in the east. The two principal rivers shared by the United States and Mexico are the Colorado River, which is primarily in the United States, but also crosses the Mexican border and empties into the Gulf of California (Figure 4.1), and the Rio Grande, a border river with tributaries in both the United States and Mexico (Figure 4.2).

Figure 4.1. Colorado River basin

SOURCE: Carter NT, Mulligan SP and Ribando Seelke C. 2017. U.S.-Mexican Water Sharing: Background and Recent Developments. Congressional Research Service

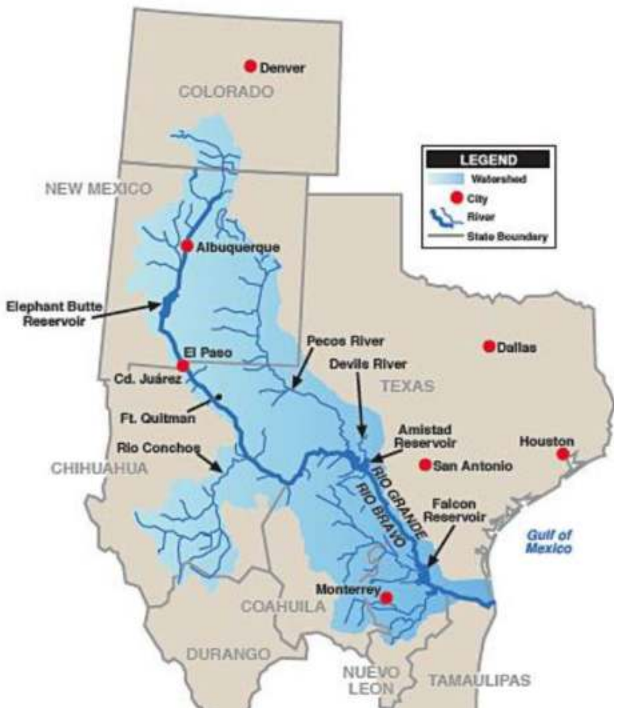


Figure 4.2. Rio Grande River basin

SOURCE: Carter NT, Mulligan SP and Ribando Seelke C. 2017. U.S.-Mexican Water Sharing: Background and Recent Developments. Congressional Research Service

Climate-proofing strategies

- Benefit sharing
- Variability management
- Disaster response
- Amendment and review
- Joint investment

Historically, as populations increased on either side of the border, intense and competitive use of river resources developed, and problems over the allocation of water emerged. A number of agreements to resolve the allocation issues were signed, with the latest being the 1944 Treaty for the Utilization of the Waters of the Colorado and Tijuana Rivers and of the Rio Grande. This treaty expanded a previous agreement (the Convention of February 1, 1933) by allotting specific water quantities of the Rio Grande and Colorado rivers to the United States and Mexico, as follows:

Allocation of the Rio Grande River (Article 4)

Water allocation to Mexico

1. An amount of water equal to all of the water reaching the main channel of the Rio Grande from the San Juan and Alamo Rivers, including return flows from the land irrigated from these two rivers;

2. Two thirds of the flow reaching the main channel of the Rio Grande from the Conchos, San Diego, San Rodrigo, Escondido and Salado Rivers, and the Las Vaca Arroyo, subject to the requirement that the remaining third is not less than an average of 350,000 acre-feet/year;

3. One half of all other flows occurring in the main channel downstream from Fort Quitman.

Water allocation to the United States

1. An amount equal to all of the waters reaching the main channel of the Rio Grande from the Pecos and Devils Rivers, Goodenough Spring and Alamito, Terlingua, San Felipe and Pinto Creeks;

2. One third of the flow reaching the main channel of the river from the Conchos, San Diego, San Rodrigo, Escondido, and Salado Rivers and Las Vacas Arroyo, which shall not be less, as an average amount in cycles of five consecutive years, than 350,000 acre-feet annually

3. One half of all other flows occurring in the main channel of the Rio Grande downstream from Fort Quitman.

In total, Mexico is obligated to deliver 350,000 acre-feet of water, annually, to the United States, from the Rio Grande River. Additionally, the two countries divide, equally, the waters from the Rio Grande, between Fort Quitman and the Gulf of Mexico.

Allocation of the Colorado River (Article 10)

Water allocation to Mexico

1. A guaranteed annual quantity of 1.5 million acre-feet of the water of the Colorado River, to be delivered in accordance with schedules formulated in advance by Mexico;

2. Any other quantities arriving at the Mexican points of diversion, but not exceeding 1.7 million acre-feet, annually;

Note that Mexico has a right to 1.5 million acre-feet, annually, and does not acquire any increased right to the waters of the Colorado River by virtue of use of those waters

Temporary exemptions

The treaty allows for certain temporary exemptions from the annual deliver requirements:

1. If Mexico is unable to provide the United States with the average annual 350,000 acre-feet from the Rio Grande, designated under the treaty, as a result of "extraordinary drought or serious accident", it is allowed to make up any water debt remaining at the end of one five-year cycle in the next five-year cycle;

2. If "extraordinary drought or serious accident" prevents the United States from delivering 1.5 million acre-feet to Mexico from the Colorado River, the water allotted to Mexico under Article 10 will be reduced in proportion to the reduction in consumption by the United States.

The Treaty does not explain the difference in the standard for reduction for each country.

Implementation of and compliance with the Treaty

- The treaty grants implementation and enforcement authority to the International Boundary and Water Commission (IBWC), which is an international body consisting of a United States Section and a Mexico Section;
- The IBWC must apply the treaty, exercising the rights and obligations of both governments under its terms, and settle all disputes that arise. Disputes are settled through the Minute process (detailed in Section 4.1.3 below).

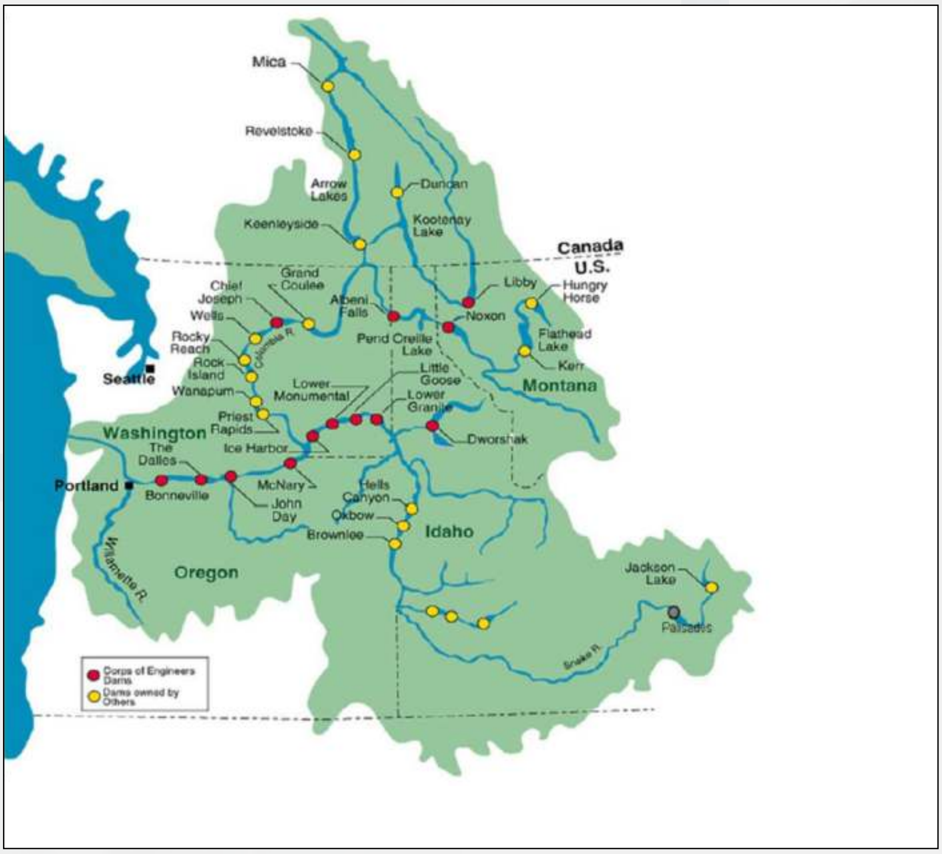
4.1.2 Response strategies for flood management – Columbia River Treaty

The Columbia River is the fourth largest river on the North American continent, measured by average annual flow, and generates more power than any other river in North America (Figure 4.3). The headwaters of the river originate in British Columbia, Canada and, although only 15% of the area of the basin lie in Canada, 38% of the annual volume, and up to 50% of peak flow volume, are from Canadian waters.

In 1948, spring flooding caused major damage both in British Columbia and in the state of Oregon on the American side of the border. The city of Vanport, Oregon was completely destroyed, which resulted in 30,000 people being displaced and 50 deaths. The magnitude of this flood event served as a trigger for action and international discussions of flood control resulted.

In 1964, Canada and the United States entered into an agreement to develop the hydroelectric potential of the Columbia River basin and to provide flood control downstream in the basin.

Figure 4.3. Columbia River Basin



SOURCE: https://engage.gov.bc.ca/columbiarivertreaty/map/

The terms of the treaty are based on the sharing of the benefits of cooperative water management, and included the construction of three reservoirs by Canada, in Canadian territory, for flood control downstream in the United States. The three reservoirs (Duncan Dam, Hugh Keenleyside Dam and Mica Dam) were constructed between 1967 and 1973. In exchange, Canada was granted:

- A payment equivalent to 50% of the estimated value of flood damages prevented in the United States. Instead of receiving an annual payment for flood control benefits, Canada elected to receive a lump sum payment of $64.4 million when each of the three Canadian dams became operational. This payment was intended to cover flood control benefits through to September 2024.

- One half of the estimated downstream power benefits generated in the United States. Canada initially sold its share of this additional power (known as the Canadian Entitlement) for $254 million to a consortium of American utilities for a period of 30 years (which expired in 2003). Since then, the Canadian Entitlement is delivered on a daily schedule to the province of British Columbia, at the Canadian/American border, for Canada to use or sell.

In the treaty, it is stipulated that the agreement between the two countries could not be terminated earlier than 60 years from the date of its ratification (2024 at the earliest) and that even if terminated, parts of the treaty pertaining to flood control would remain in effect (although the mode of flood control will change from assured control to called-upon). A notice of 10 years is required for termination (2014 at the earliest). In 2018, Global Affairs Canada initiated a formal negotiation process with the United States to renew the treaty and these negotiations remain ongoing.

4.1.3 Amendment and review mechanisms – Treaty for the Utilization of the Waters of the Colorado and Tijuana Rivers and of the Rio Grande

The 1944 Water Treaty (see Section 4.1.1 above) authorizes the IBWC to develop rules and to issue decisions or "minutes", related to the treaty's execution and interpretation. Once issued by the IBWC, a proposed minute is forwarded to the government of each country for approval. If there is no issue flagged within 30 days, the minute is adopted. If either of the governments disapprove, control over the issue is removed from IBWC and the two governments enter direct negotiations over the issue. If the two governments reach an agreement, the IBWC must take further action "necessary to carry out such agreement".

Minutes adopted, pursuant to the 1944 Water Treaty, have addressed a range of issues such as water conveyance during droughts (Minute 307, March 16, 2001), dam construction (Minute 182, September 23, 1946) and water salinity problems (Minute 242, August 30, 1973).

With respect to water allocation in the treaty, Minute 319 (November 20, 2012) entitled Interim International Cooperative Measures in the Colorado River Basin through 2017 and Extension of Minute 318 Cooperative Measures to Address the Continued Effects of the April 2010 Earthquake in the Mexicali Valley, Baja California, allowed for temporary adjustments to water deliveries to Mexico based on drought or surplus water conditions, joint investments to create greater environmental protection, measures to incentivize water conservation, and greater water storage for Mexico in upstream reservoirs. Key elements of Minute 319 included:

- The delivery of additional water (above the 1.5 million acre-feet annual delivery required by the treaty) to Mexico when water levels are high in Lake Mead;

- The reduction of deliveries to Mexico during water shortage conditions in the Colorado River basin (Mexico's annual water deliveries would be reduced if Lake Mead elevations indicated shortage conditions);

- Creation of a mechanism by which United States water deliveries to Mexico could be held in American reservoirs for subsequent delivery;

- Implementation of a pilot programme of jointly funded water efficiency and conservation projects in Mexico.

Minute 319 was set to expire on December 31, 2017 and was subsequently replaced by Minute 323, signed on September 21, 2017. Minute 323, Extension of Cooperative Measures and Adoption of a Binational Water Scarcity Contingency Plan in the Colorado River Basin, extends or replaces key elements of Minute 319 and also contains additional sections on the variability of flows arriving in Mexico and defines a Binational Water Scarcity Contingency Plan. Resolutions established in Minute 323 include:

- The extension of provisions of Minute 319 to deliver additional water to Mexico when water levels are high in Lake Mead;

- The extension of provisions of Minute 319 to reduce water deliveries to Mexico during water shortage conditions in the Colorado River basin;

- Establishment of a Binational Water Scarcity Contingency Plan under which each country saves specified volumes of water at certain low reservoir elevations for recovery when reservoir conditions improve;

- The creation of Mexico's Water Reserve, whereby U.S. water deliveries to Mexico can be held in U.S. reservoirs in the event of potential emergencies or as a result of water conservation projects in Mexico, to be available for subsequent delivery;

- Identification of measures related to variability of flows arriving in Mexico.

One of the major goals of Minute 323 is to establish cooperative efforts to avoid severe water shortages.

4.1.4 Joint management institutions – International Commission on the Protection of the Rhine

A joint TBW management body can facilitate adaptation to climate change. In particular, joint bodies can play a role in dispute settlements, implementation of joint management plans, and data and information management and sharing, particularly relating to climate change adaptation. Such a body can also include a technical branch to develop a common hydrological model of the basin and map plans around common climate-change scenarios.

The Rhine River flows from the Alps to the North Sea (Figure 4.4). With a length of 1233 km, and covering an area of about 200,000 km^2, its catchment includes nine states[67] housing about 60 million people. The Rhine River is culturally, historically, and economically one of the most important rivers in Europe.

For centuries, the Rhine River has played an important role in the history and the social, political, and economic development in Europe. However, multiple uses, conflicting interests, and environmental and flood problems in and along the river have led to the need for an integrated approach to protect the river and its basin. The basin states joined forces in 1950 to form the International Commission on the Protection of the Rhine (ICPR) with the goal of improving the sustainable development of the river and its catchment. The first common goal was to reduce water pollution and, between 1950 and 1970, a monitoring programme, uniform in application from Switzerland to the Netherlands, was established. As a result, water quality in the Rhine can be assessed reliably and on a scientific basis.

Figure 4.4. Rhine River Basin

SOURCE: https://www.rivernet.org/rhin/

67 States and regions in the Rhine basin are Switzerland, France, Germany, Luxemburg, the Netherlands, Austria, Liechtenstein, Wallonia, and Italy as well as the European Union.

Climate-proofing strategies

- Joint management
- Dispute management Framework
- Amendment and Review as knowledge improves
- Variability management

Over time, the ICPR turned to the conservation and rehabilitation of the Rhine's aquatic ecosystems. Work included the reactivation of floodplains in the basin, which act as natural flood buffers. Targets for floodplain revitalization include 160 km^2 of floodplain along the Rhine, its lowlands and 1000 km^2 across the entire Rhine watershed.

Today, the ICPR is leading the way in reducing the impacts of floods and low flows, which have both resulted in billions of euros worth of damage since the early 1990s. In particular, the ICPR is working on assessing the effects of climate change on the basin resources and adapting them. In 2015, the Commission published a first Climate Change Adaptation Strategy for the Rhine Basin, based on current hydro-climatic observations and measurements, and on predicted future scenarios. A climate change expert group has been integrated into the Commission to develop the hydrological scenarios, assess the impacts of climate change on water quality and uses, and identify options for adaptation.

4.1.5 Other noteworthy case studies

4.1.5.1 International Joint Commission (IJC)

Canada and the United States created the IJC following the recognition that each country is affected by actions in lake and river systems along the border. The two countries cooperate to manage and protect these systems.

The IJC is guided by the Boundary Waters Treaty (1909) which provides general principles for preventing and resolving disputes over shared waters and for settling other transboundary issues. The specific application of these principles is decided on a case-by-case basis.

The main responsibilities of the IJC are (i) to approve projects that affect water levels and flows across the boundary and (ii) to investigate transboundary issues and recommend solutions. In 1997, the IJC's International Watersheds Initiative was created, with climate change effects and adaptation as one of its strategic initiatives. Under this initiative, the Climate Change Guidance Framework[68] was developed to provide a process by which the resilience of ecosystems can be maintained, and the economic and social benefits and impacts within preferred ranges relative to water levels and flow management retained, in the face of future changes and uncertainties. The goal is to provide clear guidance to address climate change in policy and operations using the best available institutional and organizational science and stakeholder input. The document is expected to be iterative and will be updated as the framework is tested, and climate change knowledge is improved.

4.1.5.2 Flood and drought control – the Vuoksi River/Lake Saimaa Agreement

The discharge rule for the Vuoksi River and Lake Saimaa was an initiative by the Finnish-Russian Joint Transboundary Commission in 1973. The first plan was accepted by the Commission in 1979, jointly accepted in 1989 and then implemented in 1991. The outflow river of Lake Saimaa in Finland, the Vuoksi, flows into Russia. When the water level in the lake is within +/- 50 cm of the daily average, the outflow follows the natural rating curve. However, if the water level threatens to vary above or below this range, the release rule stipulates that the outflow should be increased or decreased in order to avoid damages. Throughout the year, information on water level, precipitation, snow and water level forecast is sent to the Russian side of the Commission. Real-time forecasts on water level and discharge from measuring sites in both countries are also made available. The working group meets annually and reviews outcomes of the previous year's activities and options for the future. If changes to the dis-

68 IJC. 2018. Climate Change Guidance Framework for IJC Boards: A Highlights Report. https://www.ijc.org/en/what/ climate/framework

charge levels are required which could result in damage, the amount of discharge is agreed upon in consultation, as well as any expected compensation from Finland to Russia[69].

4.1.5.3 Flood Amendment, review, and termination – the Syr Darya Basin Treaty

In the Syr Darya River Basin, a framework agreement requires that a periodic review be done "on water releases, production and transit of electricity, and compensations for energy losses". It also calls for the conclusion of new agreements annually[70]. The validity of the framework agreement is restricted to five years with an automatic renewal allowed for a further five years, provided that no termination notice is submitted in the previous six months. This allows for sufficient flexibility for any parties adversely affected by changed circumstances, by permitting them the right to withdraw.

4.2 MECHANISMS FOR CLIMATE-PROOFING TBW AGREEMENTS

The potential to adapt previously rigid TBW agreements to meet changing climatic and hydrologic conditions resulting from climate change is assessed in this study which builds on a number of previous publications[71,72]. The general conclusion is that the majority of TBW agreements will require modification or renegotiation to include additional protocols and mechanisms that allow for more flexibility in addressing climate uncertainties to ensure the equitable, sustainable and efficient allocation of water. Flexible allocation strategies also require provisions for successful implementation. For example, flexible allocation strategies will need to be supported by data and information about changes in water resources, a joint monitoring and evaluation mechanism to allow for proactive changes to allocation amounts, and a cooperative institution to facilitate any adaptation to changes.

As discussed in Chapter 2, adaptation to climate change revolves around managing the ongoing uncertainty and variability in water supply (both temporal and spatial). Some mechanisms have been discussed in the literature[73], while others have been determined through examining best practices. In this section, the two main strategies of climate change adaptation are discussed. The first is to manage the uncertainty of water variability, the other is to reduce this uncertainty. Finally, strengthening the enabling conditions, upon which the success of these strategies is based, will be discussed.

4.2.1 Managing uncertainty

Strategies for managing water supply variability do not attempt to reduce its variability, but try to handle it as efficiently, sustainably and equitably as possible. Many of these strategies attempt to incorporate flexibility directly into water allocations while others change treaty decisions based on alterations in variability.

Strategies for flexible water allocation:

- **Specifying a minimum downstream delivery.** An agreement with minimum flows can help to ensure that treaty requirements are met even during a water crisis. This is a simple method in which the upstream riparian country must deliver enough water downstream to support human needs and basic ecological functions. While this is less restrictive than specifying fixed amounts, downstream states may find that the minimum allocation offers little protection, while upstream countries may be concerned about being able to deliver the agreed minimum under all circumstances.

- **Allocating water based on a percentage of flow and time of flow.** This allows the flow regimes to respond to both wet and dry conditions and spreads the risk of drought among the basin states. Downstream basin states, however, are at risk if developmental changes in upstream water use occurs. This also requires flexible infrastructure and a political environment that allows for regular communication and data exchange between parties.

- **Indirect allocation mechanisms.** Processes through which allocation of resources can be determined without actually codifying the specific quantities or proportions to be shared, can also be established. These include consultations to determine future allocations, and a requirement for all riparian countries to consent to issues such as increased water use or the prioritization of water uses.

69 Markku Ollila. Joint flood risk management planning and implementation case study: River Vuoksi. Workshop on Transboundary flood risk management, Geneva, 22-23 April 2009
70 McCaffrey S.C. 2003. The need for flexibility in freshwater treaty regimes. Natural Resources Forum 27(2): 156–162
71 Cooley, H. & Gleick, P. H. (2011) Climate-proofing transboundary water agreements. Hydrol Sci. J. 56(4), 711–718.
72 Shah F.H. 2018. Climate proofing Indus Water Treaty: synergistic integration of transboundary waters' climate change adaptation practices. Margalla Papers: 22(1)
73 Fischhendler, I. 2004. Legal and institutional adaptation to climate uncertainty: a study of international rivers. Water Policy (2004) 6 (4): 281–302.

- **Framework agreements.** The development of a more general treaty would require the parties to enter into additional agreements dealing with more specific issues of water use and management. Framework agreements usually only work in basins where good political relations already exist between the states, as they require a high level of cooperation, but periodic reviews are more achievable for provisions that are detached from the main treaty.

- **Notification procedures.** Although the notification procedures established in the United Nations Watercourses Convention (UNWC) play a strong role in promoting cooperation and dispute resolution, they were developed before climate change issues came into the foreground of TBW management. The notification procedure can best be thought of as a mechanism for allocating water in river basins. An increasing number of TBW agreements, such as the Zambezi Watercourse Committee (ZAMCOM) Agreement and the Convention Creating the Niger Basin Authority, include such recommendations for notification. The majority focus on applying the procedures as set out in the UNWC, which highlights the need for environmental assessments when planning infrastructure development on a transboundary river. Notification needs to be developed in new agreements (or updated in old ones) to include validations beyond environment impact assessments such as beneficial use assessments, benefit sharing possibilities; and possible governance, organizational, financial, and operational arrangements, and defining how these will be set up for dealing with climate change issues.

- **Improving disaster response strategies.** While most transboundary institutions contain provisions for drought conditions, flood management is often ignored. Yet floods pose substantial risks, especially for downstream riparian countries, and are expected to worsen with the effects of climate change. The failure to manage these risks can have catastrophic consequences. Some examples of the types of strategies used to deal with these risks are presented in the previous section of this chapter, specifically the Treaty for the Utilization of the Waters of the Colorado and Tijuana Rivers and of the Rio Grande (Section 4.1.1) and the Vuoksi River/Lake Saimaa Agreement (Section 4.1.5.2).

- **Joint investment planning,** management, and operation. Joint investment planning can ensure that the most important needs to protect and manage basin resources are met and inform sustainable and equitable resource allocation strategies through economic efficiency and possibilities of benefit sharing. Joint basin-wide coordinated investments will allow for more effective management of water flow during periods of drought or flood together with more sustainable environmental flows.

- **Benefit sharing.** The efficient use of water, to generate maximum benefits in a river basin, can also be used to allocate water in a basin. This is a method that allows water to be used to generate overall benefits in a basin and the sharing of these benefits to ensure equitability. An example of this is seen in the Columbia River Basin described in section 4.1.2.

Introducing flexibility in allowing changes to water allocation:

- **The provision of an escape clause mechanism to cover exceptional situations.** This allows countries suffering from drought to deliver less water than they would under normal conditions, allowing them to respond to unpredictability in water supply at the same time as preserving the treaty. The use of escape clauses should be based on firm evidence of long-term (not periodic) changes in water flow regimes. This will require modeling tools to be available (see below).

- **The ability to revoke the treaty and renegotiate its terms.** Advance notice of several years is normally required before this measure can be taken.

- **Amendment and review mechanisms.** TBW institutions should include formal and informal amendment and review mechanisms to allow for the adaptations needed to response to climate change impacts. Provisions allowing periodic performance evaluation and any amendments necessary due to hydrological and development conditions or new scientific knowledge, are vital for the sustainability of the treaty. In the case of the Colorado River basin, these amendments are made through "minutes" that must be approved by all parties.

4.2.2 Reducing uncertainty

Strategies to reduce uncertainty attempt to lessen the implications of uncertainty or impact its main causes. Agreements can adopt mechanisms to increase the understanding of the system or to better understand and predict possible future scenarios.

- **Flow variability management.** Mechanisms designed to reduce the uncertainty of flow variability or alleviate its consequences include early warning systems, and the promotion of water storage structures and climate-resilient infrastructure such as nature-based solutions and the recharge, retention, and reuse of groundwater and rainwater in joint investment plans.

- **Construction bans.** This strategy prohibits the construction of infrastructure by treaty parties to reduce the uncertainty related to potentially undesirable water uses or developments in the basin. An example of this type of strategy is found in the 1970 treaty to resolve pending boundary differences and maintain the Rio Grande and Colorado River as the international boundary. In this treaty it is indicated that construction of works that may deflect or obstruct the normal flow of the river, or its flood flows, is prohibited by each contracting state.

- **Predictive models.** These mechanisms allow for the creation of models to predict future water availability and flow outcomes. Early identification allows for quick and effective reactions to possible uncertainty in water supply and, in particular, flood control. These are soft strategies that not only facilitate the creation of long-term planning, but also recognize the need to review and renegotiate, or amend, existing strategies.

- **Strengthening technical support.** Strategies to strengthen the provision of technical support under extreme conditions, such as floods or drought, or more generally to ensure cooperation in developing technological solutions to issues such as flow variability or water quality, can also help with adaption to climate change effects. The mutual gains this kind of support brings can also foster cooperation between the basin countries.

- **Monitoring and evaluation mechanisms and tools.** Consistent data and information-based monitoring of TBWs is crucial for proactive management and development of the basin resources, as well as to enforce rules and regulations. Data is needed for monitoring to be effective, and tools for data analysis and sharing are also required. Baseline metrics for natural resources and economic and social indicators which characterize the well-being of the basin need to be established as a foundation for such monitoring and evaluation. The development of monitoring tools, such as flood forecasting systems, together with rules for the collection and use of data, are essential for climate-proofing TBW agreements.

- **Joint management institutions.** A joint body can serve a variety of roles to facilitate adaptation to climate change such as: underpinning investment in knowledge and data sharing; facilitating climate change impact mitigation; ensuring ecological flows of the river systems; and relieving groundwater over-extraction and pollution. These institutions will have greater flexibility in mitigating crisis situations when they have control over certain aspects of the hydrologic cycle including the allocation of surface water, groundwater, and water quantity[74]. Conjunctive management of this sort can allow spatial and temporal tradeoffs between the various components of the hydrologic

74 Feitelson, E. (2000). The upcoming challenge: transboundary management of the hydraulic cycle. Water, Air and Soil Pollution, 123, 533–549.

cycle and between water quality and water quantity, particularly for climate change adaptation[75]. It may also be easier for joint bodies to reallocate water resources when a treaty specifies an order of preference for shared water use[76].

4.2.3 Enabling conditions

- **Enforcement, conflict resolution.** Enforcement mechanisms are imperative as they provide states, or other relevant parties, with the power to punish defectors[77], making the agreement more robust, effective, and credible. Enforcement is likely to be facilitated by the presence of a monitoring mechanism[78].

- **Joint studies and assessments.** Joint studies and assessments are required to advance a common understanding of the hydrology, socio-economic conditions, political economy, and climate change projections in TBWs.

- **Capacity building.** Through talent exchange, the critical human capacity to manage climate change induced disasters can be enhanced.

4.3 CLIMATE-PROOFING AGREEMENTS ON TBWS IN AFRICA

Climate-proofing a TBW agreement refers to incorporating provisions to ensure the sustainability of the rules, regulations, and processes defined in the agreement and allows for the flexibility to adjust to consequences of climate change. Flexible agreements can result in more predictable water supply to all riparian states, greater incentives to develop necessary water storage infrastructure and to effectively manage the operation of existing infrastructure and encourage the development of more transparent and accountable water institutions[79]. Other benefits include increased water security; enhanced food security, environment and ecosystem protection; and the reduced need for complex legal, administrative and enforcement activities.

Many TBW agreements in Africa will require climate-proofing in order to ensure the efficient, equitable and sustainable management and development of water resources and, and at the same time, protect basin communities from the economic and social implications of extreme events[80], such as droughts and floods, and changes in water availability.

As discussed earlier, there are a number of TBW agreements on Africa TBRs that already include flexibility mechanisms but their implementation is lacking. In other basins, no agreements exist or agreements fail to include all riparian countries. Figure 4.5 indicates the number of climate-proofing mechanisms in 4 TBRs with basin-wide agreements. Although 12 TBRs have basin-wide agreements (Table 3.10) only four have any of the listed mechanisms.

The main weaknesses, with respect to flexibility in TBW agreements in Africa, include:

- **A lack of enforcement of provisions.** This is a widespread problem with basin-wide agreements.

- **An absence of detail on the implementation of mechanisms.** Examples can be found in agreements written as general frameworks, without details or definitions, such as the ZAMCOM Agreement on the Zambezi River basin and the Convention on the status of the Volta River and the Establishment of Volta Basin Authority (see Section 4.3.2, below).

- **In some cases, no basin-wide agreements exist,** such as in the Nile River basin (see Section 4.3.1, below). In river basins without basin-wide agreements, cooperation remains a potentially serious problem for the management of water resources.

- **A narrow definition of water resources in a basin.** All forms of water supply in a basin, especially groundwater, should be included, which should be managed as part of a whole basin system, particularly for variability management.

- **Provisions protecting the environment and ecosystems are inadequate or excluded.**This includes considerations for issues such as water quality and environmental flows.

- **Inflexible water allocations.** This not only leads to a potential lack of cooperation within a basin, especially when water is allocated to some riparian countries and not others, but it also makes it more difficult to include provisions for water variability management.

- **A lack of groundwater agreements, especially for those TBAs that are not attached to a**

75 Mariño, M. A (2001). Conjunctive management of surface water and groundwater. In: Schumann, A. H., Acreman, M. C., Davis, R., Marino, M. A., Rosbjerg, D. & Jun, X. (Ed.). Regional Management of Water Resources. Wallingford: IAHS Publications no. 268, 165–173.
76 Goldeman, G. (1990). Adapting to climate change: a study of international rivers and their legal arrangements. Ecology Law Review, 17, 741–802.
77 Susskind, L. (1994). Environmental diplomacy: Negotiating more effective global agreements. New York, NY: Oxford University Press.
78 Keohane, R. and Martin, L. (1995). The promise of institutionalist theory. International Security, 20, 1, 39-51.
79 Ward F.A. 2013. Forging sustainable transboundary water-sharing agreements: barriers and opportunities. Water Policy 15 (2013) 386–417
80 Women are often importantly affected by extreme events through destruction of crops needed to feed families, loss of shelter, destruction of vital resources such as firewood, and worsening poverty, in general.

TBR. In groundwater management, a few options are available but are not well applied in Africa. One option is the inclusion of groundwater into basin wide TBR agreements or regional agreements, such as in the SADC region.

Figure 4.5. Climate-proofing mechanisms in basin-wide TBR agreements in Africa

Basin	Climate-proofing mechanisms										
	RBO	Allocation	Prior Notification	Uncertainty Explicit	Variability Management	Prediction Model	Joint Management	Information Exchange	Monitoring	Conflict resolution management	Amendment Mechanism
Niger	■		■		■		■	■	■	■	■
Orange	■		■	■	■		■	■		■	■
Senegal	■		■				■	■		■	■
Volta	■		■	■			■	■		■	■

Based on data from the International Freshwater Treaties Database (Oregon State University).

In the following section, TBW agreements on the Nile River, the Volta River and the Orange-Senqu River basins are reviewed for weaknesses, particularly with respect to improved flexibility, and the possibilities of enhancing the climate-proofing capabilities of TBW agreements in these basins. These three basins are regarded as being at risk according to definitions given in Chapter 3.

4.3.1 Nile River basin

The Nile River basin is highly vulnerable to the impacts of climate change. These impacts pose substantial challenges to the use and management of the Nile River resources and developing a basin-wide, climate-proofed agreement will be imperative to overcome these risks. There is no basin-wide treaty in the Nile Basin and very little cooperation over the management of water resources at this time. The main existing agreement, the CFA, which could extend basin-wide if Egypt and Sudan were to sign, still lacks the flexibility needed for climate change adaptation. In a 2019 study[81], an analysis was made of the CFA's lack of flexibility, particularly in terms of adaptation to climate change, and a proposal for a revised form of the CFA, in the form of a climate-proofed treaty, is made.

Suggestions included:

- Although flexibility is implicit in the CFA's allocation strategy based on equitable and reasonable use, anticipated impacts of climate change may change the view of what is equitable. Currently, the Council of Ministers, which is one of the organs of the Nile Basin Commission, are tasked with determining what equitable utilization means for each riparian state, but this likely leads to politicized decisions with the risk of national interests overriding equitable considerations. Egypt's dependency on the Nile will not allow for an allocation strategy in which a minimum water quantity can be provided at all times, and a lower amount delivered in drought years or even seasons. One possibility would be to have a percentage allocation strategy in the CFA with the inherent sharing of deficits and surpluses. However, given the history of Egypt's demand that their "rightful" share, as defined in the 1959 agreement, should be recognized, it may be difficult to implement a percentage allocation strategy as well.
- The CFA requires that the riparian states prevent and mitigate problems with flooding, an issue which particularly needs to be resolved, given the recent increases in flow variation in the region. However, neither the DOP nor the CFA provides guidance with respect to the operation of dams during times of flooding. To address the problems of water variation, explicit provisions for joint, coordinated operations of the GERD, the High Aswan Dam (HAD) and Sudan's reservoirs will need to be included in an updated CFA.
- To deal with hardships resulting from projected extreme drought, particularly in Egypt and Sudan, Nile River basin states will need to increase water storage capacity either through the construction of more reservoirs or though natural means, in-

81 Mahemud E. Tekuya, Governing the Nile Under Climatic Uncertainty: The Need for a Climate-Proof Basin-Wide Treaty, 59 Nat. Resources J. 321 (2019).

cluding groundwater recharge. With respect to reservoir construction, provisions to agree their placement within the basin are necessary. Additional storage should be developed upstream to avoid the massive losses of water due to evaporation, as is the case at Lake Nassar (the reservoir for the HAD), where evaporation has been measured at between 10 and 16 BCM/year[82]. Increases in air temperature, due to climate change, will increase this level over time.

- The current CFA fails to provide for periodic review of provisions, which makes it unlikely that changes in the basin, created by climate change, can be rapidly and smoothly addressed. A revised CFA should include explicit provisions for its adjustment and review, particularly regarding equitable allocation of the Nile water resources to adapt to the effects of climate change.

- The CFA allows any basin state to withdraw from the agreement with a one-year period of notice. Although provisions to withdraw from treaty obligations is important for flexibility, a one-year period may undermine the need for predictability, certainty, and security required for the effective management of the Nile River resources. A longer period of notice, such as the one found in the Columbia River Treaty, will more realistically allow for the certainty required for coordinated dam operations and for the periodic review of equitable water allocations, particularly for climate change adaptation.

- Reorganizing the structure and composition of the rulemaking and decision-making authority, to include a technical committee of experts, rather than having political appointees, would allow for more effective responses to changes in water supply in the basin. Also, since compliance at the national and basin levels is necessary for the effective implementation of provisions, a compliance or implementation committee is critical.

Climate-proofing the CFA, as discussed above, will not be easy but neither will the development of a new, basin-wide agreement. The main stumbling block is the 1959 Agreement allocating specific quantities of water to Egypt and Sudan. Although negotiations of the DOP seem to indicate that Sudan is willing to adjust, assuming there are increased benefits for them, Egypt seems unwilling to negotiate. There is also the question of the management of the White Nile. There may be a way to negotiate an agreement for the White Nile River basin countries, however there will still be the need to ensure a fixed supply of water into the main Nile for Egypt. Another possibility lies in sharing the benefits of water use in the basin, rather than the water itself[83]. These options will need to be studied further.

4.3.2 Volta River Basin

The main agreement driving the management and development of the Volta River basin is the Convention on the status of the Volta River and the Establishment of Volta Basin Authority. The Convention has provisions for: conflict resolution mechanisms; the rational and sustainable utilization of the water resources in the basin; procedures for notification, consultations and negotiations; data and information exchange; amendment mechanisms; and even ecosystem protection. However, while apparently comprehensive, the Convention currently lacks breadth and depth and leaves a number of important obligations and requirements undefined. For example, the obligation to protect and preserve ecosystems, although a progressive inclusion in a TBW agreement, lacks important definitions, obligations, and implementation procedures. This is also true of many other provisions. For example:

- The obligation to notify lacks information such as the time period allocated for the provision of notification, the duty to provide additional data or information, or procedures for notification;

- The obligation to consult and negotiate with other states concerning planned watercourse measures lacks specificity, making its implementation impractical. There are no definitions of a planned watercourse measure and there is no general obligation to consult or negotiate for other duties;

- The duty to notify in the event of emergency situations, which is important for the Volta River basin due to the probability of increased droughts and floods resulting from climate change, lacks any definition of what constitutes an emergency. As this principle is the only one in the Convention that deals with emergencies, the lack of a defined duty for basin states to create contingency plans, provide tools for predicting floods or droughts, or prevent or mitigate the effects of emergencies, makes the Convention inadequate in terms of this provision.

- Procedural requirements for the regular exchange of data and information are lacking in the Conven-

82 Shaltout M. M. and El Housry T. (1997) Estimating the evaporation over Nasser Lake in the upper Egypt from Meteosat observations. Advances in Space Research 19: 515-518.
83 Arjoon, D., A. Tilmant and M. Herrmann. (2016). Sharing water and benefits in transboundary river basins. Hydrol. Earth Syst. Sci., Vol. 20: 2135-2150.

tion. There is no explanation or agreement as to what this should entail.

As it stands, the Convention provides the framework for a TBW resource management legal regime, however, its provisions, both substantive and procedural, need to be supplemented. The Convention resembles the ZAMCOM Agreement that allows for the development of separate rules, regulations, processes and procedures to detail and define the provisions in the agreement and to make the obligations implementable. This will need to be done by the VBA for the Volta River basin. This will also allow the VBA to ensure the climate change adaptation is built into these details and definitions.

Increasing water variability, and the likelihood of more frequent extreme events occurring, could have devastating effects on the socio-economic conditions in the basin unless the VBA is provided with the legal and financial tools to implement its mandate, including the development of rules, regulations, processes, and procedures to define and detail the provisions in the Convention.

4.3.3 Orange-Senqu River Basin

The agreement establishing the ORASECOM is the only basin-wide agreement in the Orange-Senqu River basin. The other three agreements of importance in the basin are the LHWP and the establishment of JPTC, the 1992 agreement establishing the VNJIS, and the 1992 agreement creating the PWC, all of which are bi-lateral treaties. The LHWP and the VNJIS are agreements on the planning, operation, and maintenance of joint infrastructure, while the PWC and ORASECOM agreements focus on creating joint institutions to advise parties on the development and utilization of shared waters.

The flexibility mechanisms embedded in these agreements are water allocation, drought provision, amendments and reviews, revoking clauses, and institutional responsibilities[84], referring to the powers and jurisdiction conferred upon joint institutions by the cooperating parties to undertake and adjust management practices as necessary[85]. Of these, only the last three are found in the ORASECOM Agreement.

Allocation strategies are found only in the VNJIS and the LHWP agreements. Both allocate fixed volumes of water to the signing countries with some flexibility to alter, depending on changes in water requirements. Beyond these two agreements, water allocations have not been determined for the basin as a whole. South Africa strives to meet the water needs of a growing population, while Namibia is attempting to expand economic activity in the basin. National planning and project development for all basin countries will require clarification over water supply and flexible allocation. More importantly, a plan for the sustainable use of water will be necessary for climate change adaptation.

84 Kisten EJ and Ashton PJ. 2008. Adapting to Change on Transboundary Rivers: An Analysis of Treaty Flexibility on the Orange-Senqu River Basin. International Journal of Water Resources Development. Volume 24, 2008 - Issue 3: Reflections On Water Management In South Africa. Pg. 385-400

85 Feitelson, E. and Haddad, M. (1999). Identification of Joint Management Structures for Shared Aquifers, A Comparative Palestinian-Israeli Effort. World Bank Technical Paper, No. 415, (Washington D.C., The World Bank).

Recognizing the importance of developing a mutually acceptable method for sharing water in the basin, the PWC and the ORASECOM have been granted the power to advise parties on the criteria to be adopted in the allocation and utilization of common water resources.

Drought conditions are acknowledged in all of the agreements. The 1992 agreement grants power to the PWC to advise parties on the measures to alleviate short-term problems resulting from water shortages during periods of drought, while ORASECOM is tasked with advising the basin riparian countries on contingency plans for responding to drought situations. The project-focussed agreements establish more specific procedures for responding to drought events.

All these agreements include provisions for amendment and clauses that allow the parties to terminate or withdraw from the treaty. Each of these agreements also establishes joint institutions with varied responsibilities and jurisdictions.

The Orange-Senqu River basin has a history of cooperation on bilateral joint water projects, as well as having the basin-wide ORASECOM agreement. This indicates a reasonable level of cooperation between the basin states, which will make it easier for climate change adaptation to be discussed. Recently, the ORASECOM has taken steps to address some climate change issues. It has conducted a study to downscale global climate change models for the basin to generate more precise information on the impacts of climate change on the riparian countries[86]. It has also initiated a programme to monitor water quality[87] parameters, which can provide important indicators for observing the impacts of climate change at the river basin level[88]. Additionally, ORASECOM has recently received funding from the African Development Bank for a Climate Resilient Water Resources Investment Strategy, Roadmap for the operationalization of the Integrated Water Resources Management (IWRM) Plan, a Resources Mobilisation Framework, and a Feasibility Study for the Lesotho-Botswana Water Transfer Multipurpose Trans-boundary Project. The aim of this investment strategy is to propose and plan joint investments, including infrastructure projects that support climate resilience, and to plan one specific trans-boundary project.

Given that ORASECOM provides a framework agreement, there is sufficient flexibility to implement climate-proofing provisions, such as enhanced notification procedures, joint investment plans, and benefit sharing through the addition of separate policies, rules, and regulations.

4.4 RECOMMENDATIONS FOR CLIMATE-PROOFING TBW AGREEMENTS

Format:

- A framework agreement for managing and developing TBRs/TBAs, rather than an agreement that has specific provisions, will best allow for long-term flexibility.

- New agreements should define the overall management requirements in the basin (for example: equitable sharing of water or benefits, notification procedures, climate change adaptation, joint infrastructure development). Within this framework, focussed strategies, policies and instruments can be developed to implement requirements, and these can be amended over time.

- For existing TBW agreements that provide a framework, climate-proofing flexibility can be added with focussed strategies, policies, and instruments. The renegotiation of existing agreements to increase flexibility directly through specific provisions in the agreement, is more difficult and can prove cumbersome since there may be a continuous need for changes due to unforeseen events and altering needs within the basin.

Scope:

- TBRs and TBAs that lack any agreements or have agreements that are not basin-wide, will need to either renegotiate existing agreements to include all basin states, or to develop a new agreement to include all riparian states.

- TBR agreements should include all water sources in the basin, such as lakes, other natural reservoirs and groundwater.

- Agreements for TBAs that are not part of a TBR should be negotiated with all TBA countries. If a regional water strategy exists, management of TBAs can be included.

Substance:

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86 ORASECOM (Orange-Senqu River Commission). (2011). Basin-wide Integrated Water Resources Management Plan, Phase 2. Projection of Impacts under Plausible Scenarios and Guidelines on Climate Change Adaptation Strategies. ORASECOM Report, No. 009/2011.

87 ORASECOM (Orange-Senqu River Commission) (2010). Joint Baseline Survey-1: Baseline Water Resources Quality State of the Orange-Senqu River System in 2010. Compiled by Quibell G. and Rossouw J.N. for ORASECOM.

88 Blumstein S. 2017. Integrating water and climate diplomacy in the Orange-Senqu River. Climate Diplomacy Policy Brief.

- Climate-proofing TBW agreements requires the additional approach of permitting flexibility in water allocation and response strategies for managing extreme variability.

- Benefit sharing and redesigned notification procedures should be analysed as a means by which flexibility can be introduced into agreements, particularly for water allocation.

- Ecosystem protection needs to be included as part of the decision-making for allocating water.

Implementation:

- Enabling conditions such as dispute resolutions, clear enforcement, capacity building and agreed review and amendment processes, are imperative to ensure the proper application of rules and requirements defined in agreements.

Recommendations

- Financing for the climate-proofing of existing TBW agreements, or the development of more comprehensive, new climate-proofed, basin-wide agreements is critical for ensuring the sustainable and equitable management and development of TBW resources now and in the future.

5 CONCLUSIONS

Agreements and treaties on TBW resources establish rules, regulations and procedures on water use, water demand and the cooperative use of water resources.

Establishing and implementing TBW agreements are complex processes that require negotiations between basin states and that cover a range of issues, with concurrence sometimes becoming challenging. Once established, the implementation of these agreements often become subject to continuous changes in resource availability, through water supply variability caused by climate change or changing demand from both economic development and growing populations. The omission of clear mechanisms to deal with these changes has serious implications on the current and future management of TBWs. Agreements with fixed rules and procedures risk impeding the effective and sustainable management of resources, mainly through a breakdown in cooperation between riparian states as promised allocations and benefits become unobtainable.

Drawing on existing studies, literature and data, this report focuses on TBW agreements in Africa and outlines mechanisms for climate-proofing these agreements to allow for climate change adaptation. The context of climate change effects on water supply was presented, followed by an evaluation of TBRs and TBAs in Africa to assess their risks to water supply variability, and an assessment of existing TBW agreements. Consideration was given to the mechanisms embedded in these agreements and the extent to which they allow the flexibility required to adapt to climatic changes. Finally, an evaluation of climate-proofing strategies was presented and recommendations on climate-proofing existing TBW agreements, and for preparing new agreements in TBWs, were made.

The analyses revealed that 12 of the 63 TBRs in Africa are considered at-risk for climate change effects, according to the criteria used in this study. Of those at risk, half lack any agreement or have no basin-wide agreement, making the management of these river basins difficult and the risk for adverse climate change effects very high. The situation with TBAs in Africa was also found to be grim. Of the 6 TBAs that are considered to be “hotspots”, only 2 have agreements: the Taoudeni Basin and the NWSAS. Of these, only the NWSAS has an agreement with full scope signed by all parties; the Taoudeni Basin has an agreement still under preparation or which is an unsigned draft.

Climate-proofing TBW agreements will play a critical role in ensuring water security in Africa, now and into the future. Without this, a lack of flexibility in water allocations and water variability management will translate into decreased cooperation between basin states, resulting in an increase in conflict over the development and use of water resources. This study has highlighted the opportunity, and urgent need, to review TBW agreements in depth. A systematic approach to this endeavor is required and financing, to enable the climate-proofing of TBW agreements in Africa, should be a priority for global climate funds.

ANNEXES

ANNEX 1 DESCRIPTION OF INDICATORS FOR TBR ANALYSIS

INDICATOR	DESCRIPTION
	BASE INDICATORS
Change in population density	Population growth is one of the main drivers of water use for domestic, industrial, and agricultural sectors. In many regions it is a more significant determinant of future water scarcity than changes to the hydrological system induced by climate change. While efficiency gains from water-saving technologies and demand management measures may play an important role in helping to mitigate the impacts of growing water demand, there will still be important pressures on water resources in the future, especially in low-income countries with rapid population growth.
Renewable water supply	The internal water supplies available to the basin divided by the total population in the transboundary basin.
Relative water use	The mean annual withdrawals (by sectoral and total water use) divided by internal and upstream water supplies available to the transboundary basin.
	Water Quantity Thematic Group
Environmental water stress	This indicator addresses environmental stress induced by flow regime alterations due to anthropogenic impacts such as dam operation and water use. The underlying assumption of this approach is that the greater the deviations of the flow regime from natural flow conditions, the more severe are the negative impacts on the river ecosystem.
Human water stress	This indicator deals with the quantity of water available per person per year relative to the internal and upstream area water supplies, on the premise that the less water available per person, the greater the impact on human development and well-being, and the less water there is available for other sectors.
Agricultural water stress	This indicator identifies the agricultural water stress of agricultural land under irrigation. Here, the irrigation consumption-to-availability ratio is applied for estimating agricultural water stress. The results of this indicator can be compared to the human and environmental water stress indicators to see which issue is likely to be of greatest importance to the basin in terms of water quantity.
	Water Quality Thematic Group
Nutrient pollution	River nutrient pollution is caused mainly by agricultural activities (fertiliser use and wastes from livestock), urban wastewater, and atmospheric deposition of nitrogen. Contamination by nutrients (particularly forms of nitrogen and phosphorous) increases the risk of eutrophication in rivers, which can pose a threat to environmental and human health (algal blooms, decreases in dissolved oxygen, increase in toxins making water unsafe for humans and wildlife, etc.). This indicator considers river pollution from nitrogen and phosphorus.
Wastewater pollution	Untreated wastewater from human activities is one of the major threats to water quality and human health today. After use for domestic and commercial purposes, and industrial activities, water often contains remains of the respective activity (nutrients, chemical residues, and other pollutants). Untreated wastewater can threaten human health, lead to algal blooms and eutrophication (which can lead to fish die-off due to lack of oxygen). With rapidly expanding cities, often without adequate sanitation services and regulatory frameworks to control this pollution, wastewater is a significant problem in many parts of the world.

Ecosystem Thematic Group	
Wetland disconnectivity	Wetland disconnectivity is defined as the proportion of wetlands occupied by dense cropland or urban areas, assuming that human occupancy results in severing the natural physical and biological interconnections between river channels and their floodplains. Many cases of disconnectivity feature destruction and overt draining of wetlands to make them suitable for human use. Vast floodplain areas have been made dysfunctional by levee construction and river channelization to protect urban areas. Wetland disconnectivity can lead to distortion of flow patterns and the loss of local flood protection, water storage, habitat, nutrient processing and natural water purification.
Ecosystem impacts from dams	In addition to core geophysical and chemical indicators of water quantity and quality in international river basins, assessment of ecosystem state is also needed to fully evaluate basin condition. Drinking water quality, sustainable fisheries, and other basin services depend on the collective role of a diverse flora and fauna to maintain ecosystem function. While the aggregate impact of many stressors defines the state of modern river basins, one factor is highlighted as having a pre-eminent negative impact on aquatic biota: human management of water systems. Among these management systems, impoundment and reservoir operation was emblematic of stresses on aquatic ecosystems and resident biodiversity. The negative impacts on ecosystems of altering waterways through river fragmentation and flow disruption by dams, water transfers and canals must be considered for managing water resources in a sustainable way. It is no longer acceptable to draw water from nature for use in agriculture, industry, and everyday life without taking into account the role that ecosystems play in sustaining a wide array of goods and services, including water supply. Very large dams account for 85% of registered water storage worldwide. In order to compensate for considering only the impacts of very large dams on river fragmentation and flow disruption, dam density has also been factored in this indicator.
Threat to fish	In addition to the loss of fish habitat and environmental degradation, the principal factors threatening inland fisheries are fishing pressure and non-native species. Overfishing is a pervasive stress in rivers worldwide due to intensive, size-selective harvesting for commerce, subsistence, and recreation. More commonly, non-native species introductions may result from species being released for hunting or biological control as well as to form part of fish catches. Invasive alien species threaten native species as direct predators or competitors, as vectors of disease, by modifying the habitat, or altering native species dynamics.
Extinction risk	This indicator allows for the identification of transboundary basins with the highest risk of species extinction. It is based on the IUCN Red List Categories and Criteria for selected freshwater biodiversity taxa.
Governance Thematic Group	
Legal framework	This indicator is based on the assumption that the governance of a transboundary basin is guided by (amongst other things) the legal agreements in place and that they provide a framework for the allocation of resources for different uses between States. Principles of international water law have been defined to guide dialogue among riparian countries for creating effective TBW resources management. This assessment maps the presence of widely recognised key international legal principles in transboundary treaties of which countries are part of, to determine the extent to which the legal framework of the basin is guided by these principles.
Hydro-political tension	Formal management institutions governing TBRs, in the form of international water treaties (including specific provisions such as water allocation, conflict resolution, and variability management) and RBOs, can be particularly instrumental in managing disputes among fellow riparian countries arising from the development of new water infrastructure. This Indicator maps risk of potential hydro-political tension that exists when basins may be ill-equipped to deal with transboundary disputes associated to the development of new water infrastructure. The results of this indicator are based on the estimation of institutional vulnerability (expressed by the absence of relevant treaty provisions and river basins organizations), which is juxtaposed with the respective basin's ongoing and planned development of water infrastructure.
Enabling environment	This indicator considers the level of development and implementation of the 'enabling environment' for WRM in each riparian country. Enabling environment in this context refers to the national (or subnational/basin) level policies, plans, legal and institutional frameworks and management instruments required for effective WRM, development and use. Well-designed and implemented enabling environment ensures that the framework is in place to facilitate involvement of stakeholders (at all levels - community, national, private sector) in water management, and considers needs of the different users, including the environment.

Socio-economic Thematic Group	
Economic dependence on water resources	Withdrawal from water systems is often related to human activities aimed at supporting/enabling production activities to sustain economic growth. For example, freshwater is often abstracted to provide for irrigated agriculture as well as domestic and industrial needs. Understanding the degree to which economic activity is concentrated in given basins, and therefore the level of dependence on freshwater resources within basins, will help to illuminate the risk to economies within a basin should water supplies be substantially altered. This same metric can also help to assess the level of human pressure on water resources.
Societal well-being	Low levels of socio-economic development and human well-being put populations at higher risk to low and high flow extremes, and of water pollution. This indicator is composed of five sub-indicators, so the rationale for each is described in turn. 1. Access to improved drinking-water supply will indicate the efficiency of the basin's water governance structure. It will also be an indication of the population health as the lack of improved drinking-water often leads to an increase in water-related diseases, such as cholera and diarrhoea. Access to improved drinking-water can also provide economic benefits if less time is spent on securing household water supply. 2. Access to improved sanitation will be an indication of population health as the lack of improved sanitation often leads to an increase in water-related diseases, such as cholera and diarrhoea. There are also economic aspects to consider as the diseases related to poor sanitation prevent people from working. 3. Adult literacy will indicate the level of education in the basin and provide an 4. indication of the knowledge capacity to deal with issues in the basin. An educated population can more easily take on the development challenges it faces, such as ensuring environmental sustainability, increasing productivity and empowering women and creating gender equality. 5. Infant mortality rates (IMRs) serve as a useful proxy for overall poverty levels because they are highly correlated with many poverty-related metrics such as income, education levels and health status. Low IMRs are an indication of a society where the population has access to nutritious food and healthcare, whereas high IMRs are a sign of low levels of economic development. Where IMRs are highest, one would expect fluctuations in water levels, or growing water stress, would have a detrimental impact on human well-being. 6. Gini coefficients represent the level of inequality in a basin. Societal inequality is an important dimension of welfare, and indicates likely levels of participation in governance, representation in public authorities, and capacity for sound environmental management, where conflict may occur between welfare needs and environmental concerns. Gross inequality may lead to social or political unrest, which puts at risk efforts to create healthy, educated societies resilient to pressures on their water resources. The potential impacts, related to economic inequalities within political units, effect water systems with little differentiation with regard to type of water system. Thus, the problems related to poor wealth distribution will potentially add to existing problems within basins and existing linkages between water systems.
Exposure to floods and droughts	Floods and droughts, of all disasters, cause the greatest loss of life and economic losses each year, and the likelihood and severity of floods and droughts is likely to increase with climate change. Impacts of floods and droughts are felt by humans and ecosystems, and include impacts on food security, damage to infrastructure, and displacement of people. Hydrological variability induced by climate change will affect flow patterns in river systems. The risk of droughts and floods will increase, affecting both quantity and quality of water being transported through water systems. Potential human efforts to mitigate climate change effects by construction on river systems will probably further impact downstream areas.

ANNEX 2 CHARACTERISTICS OF TBW AGREEMENTS IN AFRICA

Basin Name	Country Name	Document Name	Issue Area	RBO	Allocation	Groundwater	Environment	Prior Notification	Uncertainty Explicit	Variability Management	Prediction Model	Joint Management	Info Exchange	Monitornig	Conflict Resolution Mechanism	Consultations	Amendment Mechanism	Enforcement	Alternative Scenarios
Congo/ Zaire	Angola, DRC	Convention between Belgium and Portugal regarding various questions of economic interest of the colonies Belgian Congo and Angola	Hydro-power/ Hydro-electricity		Hydropower - percentage								Y		Arbitration				
Congo/ Zaire	Burundi, DRC, Rwanda, Tanzania, Zambia	Exchange of notes accepting the protocol relative to the Tanganyika-Ruanda-Urundi Frontier	Border Issues, Fishing																
Congo/ Zaire	Angola, Burundi, Cameroon, CAR, DRC, Malawi, Rwanda, Tanzania, Zambia	General act of the conference of Berlin … Respecting: 1) freedom of trade in the basin of the Congo; 2) the slave trade; 3) neutrality of the territories in the basin of the Congo; 4) navigation of the Congo; 5) navigation of the Niger; and 6) rules for future occupation on the coast of the african continent	Navigation																
Congo/ Zaire	Burundi, DRC, Tanzania, Zambia	The Convention on the Sustainable Management of Lake Tanganyika	Water Quality, Fishing, Economic Development, Technical Cooperation/ Assistance, Navigation, Joint Management	Y		Y	Environmental services	Prior notification, Prior consent	Political, Environmental, Infrastructural			Y	Y	Y	Diplomatic Channels, Arbitration, Third party involvement	Y	Y		
Gambia	Gambia, Guinea, Senegal	Agreement between Great Britain and France	Navigation		Water -allocation of entire river														
Gambia	Gambia, Senegal	Agreement on the Integrated Development of the Gambia River Basin. Bathurst, 31 July, 1968	0																
Gambia	Gambia, Guinea, Senegal	Amendment To The Convention Relating To The Status Of The River Gambia And The Convention Relating To The Creation Of The Gambia River Basin Development Organization. 6 June, 1981	0																
Gambia	Gambia, Senegal	Convention between Senegal and Gambia. Bathurst, 18 February, 1965	0	Y								Y							
Gambia	Gambia, Guinea, Senegal	Convention relating to the creation of the Gambia River Basin Development Organization	Economic Development	Y								Y			Diplomatic Channels, Third party involvement, Permanent Judicial Organ	Y	Y		
Gambia	Gambia, Guinea, Senegal	Convention relating to the status of the River Gambia	Joint Management, Navigation				Environmental services	Prior consent				Y	Y		Diplomatic Channels, Third party involvement, Permanent Judicial Organ		Y		
Gash	Eritrea, Sudan	Exchange of notes between the United Kingdom and Italy respecting the regulation of the utilisation of the waters of the River Gash	Water Quantity		Water - fixed quantities				Flow variability, Environmental										Y
Gash	Eritrea, Sudan	Letters between the irrigation adviser and director of irrigation, Sudan government, and the controller of agriculture, Eritrea	Water Quantity		Water - fixed quantities, variable (by water availability)														

Basin Name	Country Name	Document Name	Issue Area	RBO	Allocation	Groundwater	Environment	Prior Notification	Uncertainty Explicit	Variability Management	Prediction Model	Joint Management	Info Exchange	Monitornig	Conflict Resolution Mechanism	Consultations	Amendment Mechanism	Enforcement	Alternative Scenarios
Geba-Corubal	Guinea, Guinea-Bissau	Protocol of the agreement between the Republic of Guinea and the Republic of Guinea-Bissau on the management of the Koliba-Korubal river	Joint Management, Economic Development									Y	Y	Y	Diplomatic Channels				
Incomati, Umbeluzi	Mozambique, South Africa, Swaziland	Agreement between the government of the Republic of South Africa, the government of the Kingdom of Swaziland and the government of the People's Republic of Mozambique relative to the establishment of a tripartite permanent technical committee	Water Quantity		Water - Consultation				Flow variability	Dry season control		Y		Y			Y		
Incomati	South Africa	Agreement on the development and utilisation of the resources of the Komati River Basin between the government of the Republic of South Africa and the government of KaNgwane	Water Quantity, Infrastructure/ Development		Water								Y		Diplomatic Channels, Arbitration				
Incomati	South Africa, Swaziland	Treaty on the development and utilisation of the water resources of the Komati River Basin between the government of the Kingdom of Swaziland and the government of the Republic of South Africa	Water Quantity		Water - fixed quantities, variable (by water availability); Water - fixed quantities, recoupable (in later periods if not met)		Environmental services	Prior notification, Prior consent	Flow variability, Environmental, Political, Financial, Infrastructural, Flow variability, Treaty Implementation	Dry season control	Y	Y			Diplomatic Channels, Arbitration				Y
Incomati	Mozambique, South Africa, Swaziland	Tripartite permanent technical committee ministerial meeting of ministers responsible for water affairs.	Water Quantity		Water - fixed quantities, recoupable (in later periods if not met)								Y						
Incomati, Limpopp, Maputo, Umbeluzi	Mozambique, South Africa	Joint Water Commission terms of reference	Joint Management				Water quality		Flow variability	Both		Y	Y		Diplomatic Channels		Y		
Incomati, Maputo	South Africa, Swaziland	Treaty on the establishment and functioning of the joint water commission between the government of the Republic of South Africa and the government of the Kingdom of Swaziland	Water Quantity		Water - Consultation		Water quality		Flow variability	Dry season control		Y	Y		Diplomatic Channels, Third party involvement		Y		
Incomati, Maputo	Mozambique, South Africa, Swaziland	Tripartite Interim Agreement between the Republic of Mozambique and the Republic of South Africa and the Kingdom of Swaziland for co-operation on the protection and sustainable utilisation of the water resources of the Incomati and Maputo watercourses	Joint Management		Water - prioritization of uses (e.g. domestic use first, hydropower second..); Water - fixed quantities	Y	Environmental services	Prior consultations	Flow variability, Environmental, Infrastructural	Both	Y	Y	Y	Y	Diplomatic Channels, Arbitration		Y		Y
Kunene	Angola, Namibia	Agreement between South Africa and Portugal regulating the use of the water of the Cunene River	Hydro-power/Hydro-electricity		Water - percentage of flow			Prior notification, Prior consent	Flow variability			Y			Arbitration				Y
Kunene	Angola, Namibia	Agreement between the government of the Republic of South Africa and the government of Portugal in regard to the first phase of development of the water resource of the Cunene River Basin	Water Quantity		Water - fixed quantities and percentage			Prior consent	Flow variability	Both		Y	Y	Y					
Kunene	Angola, Namibia	Agreement In Regard To The Development And Utilization Of The Water Potential Of The Kunene River. 18 September, 1990	0																
Lake Chad	Cameroon, Chad, Niger, Nigeria	Accord pertaining to the creation of funds for the development of the Chad Basin Commission	Joint Management, Economic Development												Commission, Arbitration				
Lake Chad	Cameroon, Chad, Niger, Nigeria	Agreement establishing the Lake Chad basin Commission development fund. Yaounde, 22 October, 1972	0																
Lake Chad	Cameroon, Chad, Niger, Nigeria	Convention and statutes relating to the development of the Chad Basin	Economic Development	Y		Y		Prior consultations				Y	Y		Commission, Arbitration, Permanent Judicial Organ		Y	Y	

Basin Name	Country Name	Document Name	Issue Area	RBO	Allocation	Groundwater	Environment	Prior Notification	Uncertainty Explicit	Variability Management	Prediction Model	Joint Management	Info Exchange	Monitornig	Conflict Resolution Mechanism	Consultations	Amendment Mechanism	Enforcement	Alternative Scenarios
Limpopo	Mozambique, South Africa	Agreement between the government of the Republic of South Africa, the government of the Kingdom of Swaziland and the government of the People's Republic of Mozambique relative to the establishment of a tripartite permanent technical committee	Water Quantity		Water - Consultation				Flow variability	Dry season control		Y		Y			Y		
Limpopo	Botswana, South Africa	Agreement on the Establishment of the Joint Permanent Commission for Cooperation	0																
Limpopo	Botswana, South Africa	Agreement on the Establishment of the Joint Permanent Technical Commission. 1997	0																
Limpopo	Mozambique, South Africa	Joint Water Commission terms of reference	Joint Management				Water quality		Flow variability	Both		Y	Y		Diplomatic Channels		Y		
Moa	Liberia, Sierra Leone	Agreement between Great Britain and France respecting the boundary between Sierra Leone and French Guinea	Border Issues					Prior consent											
Niger	Benin, Burkina Faso, Cameroon, Chad, Guinea, Ivory Coast, Mali, Niger, Nigeria	Act regarding navigation and economic co-operation between the states of the Niger Basin	Economic Development									Y			Diplomatic Channels, Arbitration, Permanent Judicial Organ			Y	
Niger	Niger, Nigeria	Agreement between the Federal Republic of Nigeria and the Republic of Niger concerning the equitable sharing in the development, conservation and use of their common water resources	Water Quantity			Y	Environmental services	Prior consultations				Y	Y	Y	Commission, Third party involvement				
Niger	Benin, Niger	Agreement between the Republic of Niger and the Republic of Benin relative to the realization of the hydroelectric management of the Dyondyonga site on the Mékrou river, signed at Contonou	Hydro-power/Hydro-electricity									Y		Y			Y		
Niger	Benin, Burkina Faso, Cameroon, Chad, Guinea, Ivory Coast, Mali, Niger, Nigeria	Agreement concerning the Niger River Commission and the Navigation and Transport on the River Niger Revised on 2nd February, 1968 and 15th June, 1973	0									Y	Y		Commission	Y	Y		
Niger	Unknown	Agreement concerning the Niger River Commission and the Navigation and Transport on the River Niger. Done at Niamey, on 25 November 1964 [Partial Termination]. 13 January, 1984	0	Y								Y							
Niger	Benin, Burkina Faso, Cameroon, Chad, Guinea, Ivory Coast, Mali, Niger, Nigeria	Agreement concerning the Niger River Commission and the Navigation and Transport on the River Niger. Done at Niamey, on 25 November 1964 [Rectification]. Niamey, 15 May, 1968	0									Y					Y		
Niger	Benin, Burkina Faso, Cameroon, Chad, Guinea, Ivory Coast, Mali, Niger, Nigeria	Agreement concerning the Niger River Commission and the navigation and transport on the River Niger. Done at Niamey, on 25 November 1964." Amendment to article 2 of the above said agreement	0																
Niger	Benin, Burkina Faso, Cameroon, Chad, Guinea, Ivory Coast, Mali, Niger, Nigeria	Agreement concerning the River Niger Commission and the navigation and transport on the River Niger	Economic Development	Y			Environmental services	Prior notification, Prior consultations				Y	Y		Commission		Y	Y	
Niger	Benin, Burkina Faso, Cameroon, Chad, Guinea, Ivory Coast, Mali, Niger, Nigeria	Convention creating the Niger Basin Authority	Economic Development							Both		Y	Y	Y	Commission				

Basin Name	Country Name	Document Name	Issue Area	RBO	Allocation	Groundwater	Environment	Prior Notification	Uncertainty Explicit	Variability Management	Prediction Model	Joint Management	Info Exchange	Monitornig	Conflict Resolution Mechanism	Consultations	Amendment Mechanism	Enforcement	Alternative Scenarios
Niger	Algeria, Benin, Burkina Faso, Cameroon, Chad, Cote d'Ivoire, Guinea, Mali, Mauritania, Niger, Nigeria	General act of the conference of Berlin … Respecting: 1) freedom of trade in the basin of the Congo; 2) the slave trade; 3) neutrality of the territories in the basin of the Congo; 4) navigation of the Congo; 5) navigation of the Niger; and 6) rules for future occupation on the coast of the african continent	Navigation																
Niger	Mali, Niger	Protocol of the agreement between the Republic of Niger and the Republic of Mali relative to cooperation in the utilization of resources in water of the Niger river	Joint Management						Flow variability			Y	Y	Y					
Niger	Mali, Niger	Protocole d'accord entre la République du Niger et la République du Mali relatif à la réalisation des barrages de Taoussa au Mali et de Kandadji au Niger	0				Environmental services								Diplomatic Channels				
Niger	Benin, Burkina Faso, Cameroon, Chad, Guinea, Ivory Coast, Mali, Niger, Nigeria	Revised convention pertaining to the creation of the Niger Basin Authority, signed at N'Djamena	Joint Manage-ment, Economic Development	Y			Water quality, Environmental services					Y		Y	Commission, Diplomatic Channels	Y	Y		
Niger	Algeria, Benin, Burkina Faso, Cameroon, Chad, Guinea, Cote d'Ivoire, Mali, Niger, Nigeria	Revised financial procedures of the Niger Basin Authority, done at Ndjamena	Joint Management																
Nile	Burundi, Rwanda, Tanzania, Uganda	Accession of Uganda to the agreement per-taining to the creation of the organization for the management and development of the Kagera river basin	Joint Management										Y						
Nile	DRC, South Sudan	Agreement between Great Britain and the Independent State of the Congo, modifying the agreement signed at Brussels 12 May 1894, relating to the spheres of influence of Great Britain and the Independent State of the Congo in East and Central Africa	Border Issues					Prior consent							Permanent Judicial Organ				
Nile	Egypt, Sudan	Agreement between the government of the United Arab Republic and the government of Sudan for full utilization of the Nile waters	Flood control/relief, Water Quantity		Water - fixed quantities				Flow variability		Y	Y		Y	Commission				
Nile	DRC, Rwanda	Agreement between the United Kingdom and Belgium regarding water rights on the boundary between Tanganyika and Ruanda-Urundi	Water Quantity		Water - percentage of flow		Water quality	Prior notifi-cation			Y			Y	Arbitration				Y
Nile	Burundi, Rwanda, Tanzania, Uganda	Agreement for the establishment of the organization for the management and development of the Kagera river basin (with attached map), Concluded at Rusumo, Rwanda	Joint Manage-ment, Economic Development	Y			Environmental services					Y			Diplomatic Channels, Arbitration		Y		
Nile	Egypt, Kenya, Sudan, Tanza-nia, Uganda	Agreement for the Hydrometeorological Survey of Lakes Victoria, Kyogo and Albert (Mobutu Sese Seko)	0																
Nile	Kenya, Tanza-nia, Uganda	Agreement to initiate program to strengthen regional coordination in management of resourc-es of Lake Victoria	Joint Management				Water quality		Infrastructural			Y	Y	Y			Y		
Nile	Burundi, Rwanda, Tanzania, Uganda	Amendment to the Agreement for the Establishment of an Organization to Manage and Develop The Kagera River Basin. 19 May, 1978	0																

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Nile	Kenya, Tanzania, Uganda	Convention for the establishment of the Lake Victoria Fisheries Organization with annex and final act	Joint Management, Fishing, Water Quality				Environmental services		Scientific			Y	Y	Y	Diplomatic Channels, Arbitration	Y	Y		
Nile	Ethiopia, Sudan	Exchange of notes between Great Britain and Ethiopia	Water Quantity		Water														
Nile	Egypt, South Sudan, Sudan	Exchange of notes between His Majesty's government in the United Kingdom and the Egyptian Government in regard to the use of the waters of the River Nile for irrigation purposes	Water Quantity		Water - fixed quantities vary according to time of the year			Prior consent	Treaty Implementation, Flow variability, Political, Data, Financial					Y	Diplomatic Channels, Arbitration				
Nile	Ethiopia	Exchange of notes between the United Kingdom and Italy respecting concessions for a barrage at Lake Tsana and a railway across Abyssinia from Eritrea to Italian Somaliland	Irrigation, Infrastructure Development		Water - prioritization of uses (e.g. domestic use first, hydropower second..)				Political	Dry season control									
Nile	Egypt, Uganda	Exchange of notes constituting an agreement between the government of the United Kingdom of Great Britain and Northern Ireland and the government of Egypt regarding the construction of the Owen Falls Dam in Uganda	Hydro-power/Hydro-electricity		Pollution														
Nile	Egypt, Uganda	Exchange of notes constituting an agreement between the government of the United Kingdom of Great Britain and Northern Ireland and the government of Egypt regarding the construction of the Owen Falls Dam, Uganda	Hydro-power/Hydro-electricity																
Nile	Egypt, Uganda	Exchange of notes constituting an agreement between the Government of the United Kingdom of Great Britain and Northern Ireland on behalf of the government of Uganda and the government of Egypt regarding cooperation in meteorological and hydrological surveys in certain parts of the Nile Basin	Hydro-power/Hydro-electricity										Y	Y					
Nile	Egypt	Exchange of notes constituting an agreement between the United Kingdom of Great Britain and Northern Ireland and Egypt regarding the utilisation of profits from the 1940 British government cotton buying commission and the 1941 joint Anglo-Egyptian cotton	Water Quantity																
Nile	Egypt, Uganda	Exchanges of notes constituting an agreement between the government of the United Kingdom of Great Britain and Northern Ireland and the government of Egypt regarding the construction of the Owen Falls Dam, Uganda	Hydro-power/Hydro-electricity					Prior consultations		Both					Diplomatic Channels, Arbitration	Y			

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Nile	Egypt, Ethiopia	Framework for general co-operation between the Arab Republic of Egypt and Ethiopia	Water Quantity						Flow variability							Y			
Nile	Egypt, Sudan	Jebel Awilya Compensation Agreement. 1932	0																
Nile	Egypt, Sudan	Protocol (to the November 8, 1959 agreement) Concerning the Establishment of the Permanent Joint Technical Committee. Cairo, 17 January, 1960	0									Y							Y
Nile	Eritrea, Sudan	Protocol between Great Britain and Italy for the demarcation of their respective spheres of influence in Eastern Africa	Border Issues, Water Quantity																
Nile	Kenya, Tanzania, Uganda	Protocol for Sustainable Development of Lake Victoria Basin. Arusha, 29 November, 2003	0	Y		Y	Environmental services	Prior notification, Prior consultations	Flow variability, Environmental, Infrastructural	Both		Y	Y	Y	Commission, Arbitration		Y		
Nile	Ethiopia, Sudan	Treaties between Great Britain and Ethiopia, relative to the frontiers between Anglo-Egyptian Soudan, Ethiopia, and Erythroea (Railway to connect Soudan with Uganda)	Water Quantity					Prior consent											
Nile	Kenya, Tanzania, Uganda	Treaty for the Establishment of the East African Community signed at Arusha	0				Environmental services	, Prior notification	Flow variability, Environmental	Dry season control	Y		Y	Y	Arbitration	Y	Y		
Okavango	Botswana, Namibia	Agreement Between the Government of Botswana and the Republic of Namibia on the Establishment of a Joint Water Commission. Windhoek, 13 November, 1990	0		Water - unclear		Water quality					Y	Y		Diplomatic Channels		Y		
Okavango	Angola, Botswana, Namibia	Agreement between the governments of the Republic of Angola, the Republic of Botswana, and the Republic of Namibia on the establishment of a permanent Okavango River Basin Water Commission (OKACOM)	Water Quantity	Y	Water - Consultation		Water quality	Prior notification	Flow variability		Y	Y	Y		Diplomatic Channels		Y		
Orange	Botswana, Namibia	Agreement Between the Government of Botswana and the Republic of Namibia on the Establishment of a Joint Water Commission. Windhoek, 13 November, 1990			Water - unclear		Water quality					Y	Y		Diplomatic Channels		Y		
Orange	Namibia, South Africa	Agreement between the government of the Republic of Namibia and the government of the Republic of South Africa on the establishment of a permanent water commission	Water Quantity		Water - Consultation		Water quality		Flow variability	Dry season control		Y	Y		Commission, Diplomatic Channels				

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Orange	Botswana, Lesotho, Namibia, South Africa	Agreement Between the Governments of the Republic of Botswana the Kingdom of Lesotho the Republic of Namibia and the Republic of South Africa on the Establishment of the Orange-Senqu Commission. Windhoek, 3 November, 2000	0	Y			Environmental services	Prior consultations	Flow variability, Environmental, Infrastructural	Both		Y	Y		Commission, Arbitration		Y		Y
Orange	Lesotho, South Africa	Agreement on the Establishment and Operation of a Common Works Area at the Caledon River for the Purpose of the Implementation of the Lesotho Highland Water Project. 12 June, 1989	0																
Orange	Namibia, South Africa	Agreement on the Vioolsdrift and Noordoewer Joint Irrigation Scheme Between the Government of the Republic of South Africa and the Government of the Republic of Namibia. Pretoria, 26 April, 1993	0																
Orange	Lesotho, South Africa	Ancillary agreement to the deed of undertaking and relevant agreements entered into between the Lesotho Highlands Development Authority and the government of the Republic of South Africa	Infrastructure/ Development										Y		Diplomatic Channels, Arbitration				
Orange	Lesotho, South Africa	Protocol IV to the treaty on the Lesotho Highlands Water Project: supplementary arrangements regarding phase IA	Infrastructure/ Development						Financial			Y			Commission, Diplomatic Channels, Arbitration				
Orange	Lesotho, South Africa	Protocol VI to the treaty on the Lesotho Highlands Water Project: supplementary arrangements regarding the system of governance for the project	Infrastructure/ Development, Water Quantity				Water quality		Financial, Infrastructural		Y	Y	Y	Y	Commission, Diplomatic Channels, Arbitration				
Orange	Lesotho, South Africa	Treaty on the Lesotho Highlands Water Project between the government of the Republic of South Africa and the government of the Kingdom of Lesotho	Flood control/relief, Hydro-power/ Hydro-electricity, Water Quantity		Water - fixed quantities, fixed quantities, recoupable (in later periods if not met)		Water quality	Prior consent	Effectiveness of treaty regime, Treaty implementation, Flow variability, Environmental, Political	Both	Y	Y	Y	Y	Commission, Diplomatic Channels, Arbitration		Y	Y	Y
Senegal	Mali, Mauritania, Senegal	Agreement Establishing a Permanent Joint Technical Committee. 18 August, 1979	0																
Senegal	Mali, Mauritania, Senegal	Amendments To The Convention Concerning The Status Of The Senegal River And Convention Establishing The Senegal River Development Organization. 11 December 1979	0																
Senegal	Mali, Mauritania, Senegal	Convention concluded between Mali, Mauritania, and Senegal relative to the legal statute of common works	Joint Management, Infrastructure/ Development						Political, Environmental, Infrastructural			Y			Diplomatic Channels, Third party involvement, Permanent Judicial Organ		Y		

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Senegal	Guinea, Mali, Mauritania, Senegal	Convention of Bamako	Economic Development					Prior consent				Y	Y		Commission				
Senegal	Guinea, Mali, Mauritania, Senegal	Convention of Dakar	Hydro-power/ Hydro-elec-tricity															Y	
Senegal	Mali, Mauritania, Senegal	Convention pertain-ing to the creation of the organization for the management of the Senegal river, signed at Nouakchott	Economic Development, Joint Manage-ment	Y	Consulta-tion							Y			Diplomatic Channels, Third party involvement, Permanent Judicial Organ	Y	Y		
Senegal	Mali, Mauritania, Senegal	Convention relating to the statute of the Senegal river	Economic Development, Joint Manage-ment				Environmen-tal services	Prior consent				Y			Diplomatic Channels, Arbitration, Third party involvement, Permanent Judicial Organ		Y		
Senegal	Guinea, Mali, Mauritania, Senegal	Convention Relating to the Statute of the Senegal River. Dakar, 7 February, 1964	0	Y			Environmen-tal services	Prior noti-fication				Y			Commission, Diplomatic Channels, Arbitration, Permanent Judicial Organ		Y		
Senegal	Guinea, Mali, Mauritania, Senegal	General Scheme for Development of the Senegal River Basin. 30 January 1970	0																
Senegal	Mali, Mauritania, Senegal	Senegal River Water Charter	0	Y	Water - prioritization of uses (e.g. domestic use first, hydropower second..)	Y	Environmen-tal services	Prior notifica-tion, Prior consulta-tions, Prior consent	Flow variability, Environ-mental, Flow variabil-ityFlow variability			Y	Y		Diplomatic Channels, Arbitration, Permanent Judicial Organ	Y	Y		
Senegal	Guinea, Mali, Mauritania, Senegal	Statute of the Orga-nization of Senegal River States	0	Y								Y					Y		
Volta	Benin, Burkina Faso, Gha-na, Ivory Coast, Mali, Togo	Convention on the status of the Volta River and the Es-tablishment of Volta Basin Authority	Joint Manage-ment, Water Quality, Naviga-tion, Economic Development	Y		Y	Environmen-tal services	Prior consent	Flow variability			Y	Y		Commission, Third party involvement, Permanent Judicial Organ	Y	Y		
Zambezi	Mozam-bique	Agreement between South Africa and Portugal relating to hydropower development on the Zambesi River [Untitled]	Hydro-power/ Hydro-elec-tricity																
Zambezi	Malawi, Mozam-bique	Agreement between the Government of the United Kingdom and Northern Ireland (acting on their behalf and on behalf of the Government of the Federation of Rhodesia and Nyasaland) and the Government of Portugal regarding the Nyasaland-Mo-zambique Frontier. Lisbon, 18 Novem-ber, 1954	0																
Zambezi	Mozam-bique, South Africa	Agreement between the governments of the Republic of Portugal, the People's Republic of Mozambique and the Republic of South Africa relative to the Cahora Bas-sa Project	Flood control/ relief, Hy-dro-power/Hy-dro-electricity						Environmen-tal, Political, Financial	Both		Y	Y			Y	Y	Y	

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Zambezi	Zambia, Zimbabwe	Agreement between the Republic of Zimbabwe and the Republic of Zambia concerning the utilization of the Zambesi River	Water Quantity, Hydro-power/ Hydro-electricity		Hydropower - percentage			Prior notification, Prior consultations, Prior consent	Financial, Effectiveness of treaty regime		Y	Y	Y	Y	Arbitration	Y	Y		
Zambezi	Botswana, Mozambique, Tanzania, Zambia, Zimbabwe	Agreement on the action plan for the environmentally sound management of the common Zambesi River System	Flood control/ relief, Water Quantity				Environmental services		Flow variability, Environmental, Infrastructural	Flood control		Y	Y	Y			Y		
Zambezi	Angola, Botswana, Malawi, Mozambique, Namibia, Tanzania, Zambia, Zimbabwe	Agreement on the Establishment of the Zambezi Watercourse Commission	0	Y	Water - unclear	Y	Environmental services	Prior notification	Flow variability, Environmental, Flow variability	Both		Y	Y		Commission, Diplomatic Channels, Arbitration	Y	Y		
Zambezi	Zambia, Zimbabwe	Agreement relating to the Central African Power Corporation	Hydro-power/ Hydro-electricity		Water								Y		Commission				
Zambezi	Mozambique	Agreement to Purchase electricity from Cabora-Bassa Scheme. Lisbon, 19 September, 1969	0																
Zambezi	Mozambique, Zambia, Zimbabwe	Convention with agreements regarding use of Zambezi waters and effects of the proposed Kariba Dam. Salisbury, 30 and 31 May, 1950	0																
Zambezi	Namibia, Zambia	Exchange of notes between the Union of South Africa and Northern Rhodesia regarding the Eastern Boundary between the Caprivi Strip and Northern Rhodesia and the grant of privileges to Northern Rhodesia natives on the Caprivi Islands. Pretoria and Cape Town, 25 July 1933	Border Issues, Fishing																
Zambezi	Malawi, Mozambique	Exchange of notes constituting an agreement between Her Majesty's government in the United Kingdom of Great Britain and Northern Ireland and the Portuguese government providing for the Portuguese participation in the Shiré Valley Project	Flood control/ relief, Hydro-power/Hydro-electricity																
Zambezi	Malawi, Mozambique	Treaty between Great Britain and Portugal, defining their respective spheres of influence in Africa	Border Issues												Commission, Arbitration				

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