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When the water runs dry: supporting adaptive governance in transboundary river basins

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ABSTRACT

Impacts of global climate change will primarily be felt through the water cycle. Adaptation to changing conditions in transboundary basins is an important precondition to ensure regional sustainable development and political stability. However, adaptation measures in one basin country can affect water resources and adaptation options elsewhere, therefore often requiring coordinated or joint responses by riparian countries. The paper examines the potential of climate policy instruments in strengthening adaptation to changes in transboundary river basins in North America's Colorado River Basin and Southern Africa's Orange-Senqu River Basin. It finds that climate policy instruments are yet rarely employed to jointly manage adaptation in shared rivers but nonetheless harbour great potential.

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Introduction

At least 310 of the world's river basins are shared by multiple countries (McCracken & Wolf, 2019). Many riparian countries (hereafter referred to as “riparians”) have signed international water treaties or have created cooperative institutions such as river basin organizations to coordinate various activities and to jointly govern these resources.

Today, many of these shared water resources and institutions are under increasing stress from developments such as population growth, industrialization, and urbanization (e.g., Wohl, 2010). These shared water resources are expected to be further aggravated by the impacts of climate change in complex and sometimes non-linear ways (e.g., Draper & Kundell, 2007; Whitehead et al., 2015). Climate change is expected to further increase variability in precipitation, thereby increasing the frequency and intensity of extreme weather events like floods and droughts. Therefore, certain locations are expected to experience decreasing rainfall and higher temperatures. Furthermore, climate change can deteriorate water quality through higher concentrations of pollutants in rivers as a result of extreme rain events or drought (Hosseini et al., 2017).

While climatic variability has generally been linked with higher likelihoods of transboundary conflict (e.g., Hendrix & Salehyan, 2012) and conflict intensity (Papaioannou, 2016), multiple benefits can be derived from climate change adaptation at the basin level. For example, basin approaches to climate change adaptation can avoid potential negative

effects that may arise from unilateral action in one part of the basin. Additionally, pooling resources and using optimal locations for adaptation projects provides greater opportunities for investments.

To derive these benefits, it is therefore necessary to bolster the capacity of transboundary water institutions to manage climate change impacts, thereby increasing the likelihood of long-term, stable cooperation between states. Acknowledging this need, scholars have increased their attention on climate change and effectively managing adaptation, identifying several institutional conditions and mechanisms that support climate change adaptation in transboundary water basins. These include flexible allocations in water treaties (e.g., Drieschova et al., 2008; Milman et al., 2012), data and information sharing mechanisms (e.g., Gerlak et al., 2011; Schulze & Schmeier, 2012), or allocating additional funding for adaptation activities (e.g., Schulze & Schmeier, 2012).

Climate researchers and policy actors also emphasize the significance of specific climate change adaptation instruments like vulnerability assessments, adaptation planning, and sustainable funding through the use of specific climate funding mechanisms.¹ While these climate change adaptation instruments have been researched in the context of national adaptation processes and capacities, there is very little research on these mechanisms within the context of transboundary river basins (one exception being Earle et al., 2015).

The aim of this paper, therefore, is to examine how these two fields of research could be combined and how mechanisms from the context of climate governance could be used to strengthen and complement existing approaches to adaptation in transboundary river basin contexts. To examine this question, this paper first outlines adaptation components based on hydro-politics and climate change research literature. It then examines these components within two internationally shared river basins: the Colorado River Basin in North America and the Orange-Senqu River Basin in Southern Africa.

Research approach

The definition of climate change adaptation is still debated widely (see Berrang-Ford et al., 2019; Engle, 2011). This paper employs a broad definition of the term, referring to adaptation as the ‘process of adjustment to actual or expected climate and its effects’ to avoid harm or exploit opportunities (IPCC (Intergovernmental Panel on Climate Change), 2015, p. 118). In line with this understanding, adaptation capacities relate to the resources and activities of water governance institutions that help to prevent or mitigate impacts of climate change. These activities can address climate change adaptation explicitly, such as wetland restoration, but also can be comprised of actions that are not necessarily labelled as ‘adaptation’, such as building water storage infrastructure or preserving floodplains to better respond to floods.

In the following sections we outline our approach for analysing climate change adaptation in transboundary river basins (Figure 1). Realizing that our selection of key mechanisms is not exhaustive, we have selected key mechanisms that influence climate change adaptation that have been frequently identified in current water governance and climate change literature. In combining elements from these two strands of literature we aim to identify synergies and develop a better understanding of the role of climate change instruments in supporting adaptation in transboundary basin settings.

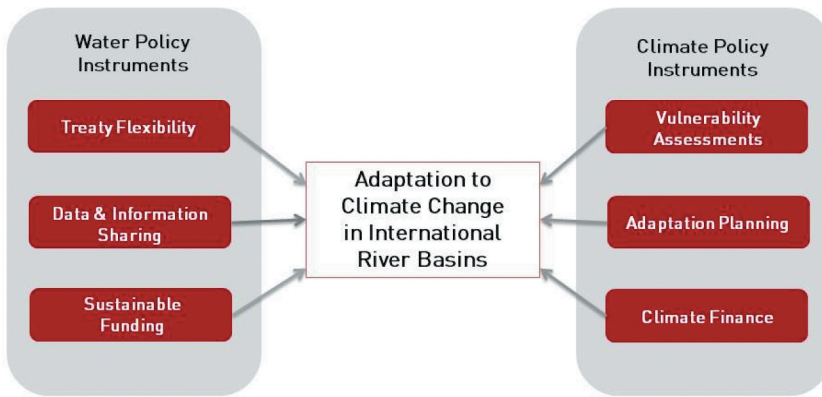


Figure 1. Adaptation elements analysed within this article.

Examining the research on adaptation to climate change from hydro politics and broader water governance literature reveals that many studies have focused on *legal provisions and the design of international water treaties (treaty flexibility)* to ensure peaceful neighbourly relations under changing environmental conditions (e.g., Bakker, 2007; Dinar et al., 2015; Drieschova et al., 2008; De Stefano et al., 2012). Several factors seem to influence adaptiveness to environmental changes more broadly and climate change more specifically, such as flexible water allocation mechanisms that allow to address different water availabilities in a basin (Cooley et al., 2009; Dinar et al., 2015), specific flood provisions (Bakker, 2007) or guidelines for data sharing or prior notification (e.g., planned infrastructure measures) (Blumstein, 2015; Schmeier, 2011).

Scholars have also argued that *data and information sharing* at the river basin level (e.g., through a river basin organization) is important for successful river basin planning and management (e.g., Gerlak et al., 2011; Meijerink & Huitema, 2017) and particularly significant for addressing climate change (Schulze & Schmeier, 2012; Timmerman et al., 2017). These authors generally argue that sharing or jointly generating data and information leads to an improved and mutual understanding of the causes, expected future developments, and impacts of environmental changes and ultimately supports agreement on how to approach or solve a certain problem.

Finally, the sustainable *funding of adaptation activities* has been argued to be a relevant factor for climate change adaptation (Blumstein, 2015; Schmeier, 2011; World Bank, 2019). Successfully implementing adaptation relevant activities in shared river basins requires financial and technical resources – often in addition to existing activities. This can be a challenging issue for riparians, particularly in the developing world. Here, external funding provided by bilateral donors or multilateral funding mechanisms (such as Global Environment Facility’s focal area of international waters) can help.

While the previous sections outlined key issues discussed in water governance research, we now turn to specific factors debated in climate change research that may potentially support adaptation in transboundary river basins. Acknowledging that this is a large body of research that cannot be captured comprehensively here, we select aspects (vulnerability assessments, adaptation planning, and climate finance) frequently mentioned in the literature that facilitate adaptation to climate change in transboundary settings but have not yet been explored in depth.

First, although little scholarly research exists, some policy reports suggest that *vulnerability assessments* can support adaptation capacities in transboundary basins (Koeppel, 2013; United Nations Economic Commission for Europe & International Network of Basin Organizations (UNECE & INBO), 2015).² Vulnerability assessments are tools that help identify the vulnerabilities of societies and ecosystems towards the impacts of climate change. They fulfil diverse purposes, such as detecting current and potential climate change hotspots, helping to identify suitable adaptation interventions, and tracking changes in vulnerability over time.

While most vulnerability assessments are conducted at the (sub-) national level, they can also be a useful tool for adaptation in transboundary river basin context. Assessing the biophysical and social vulnerabilities to climate change in shared river basins provides important knowledge for preventing adaptation activities in one riparian country from increasing vulnerabilities in another basin country (Koeppel, 2013; UNECE & INBO, 2015). In addition, such transboundary vulnerability assessments can provide the basis to identify potential synergies for joint activities, such as building dams or restoring/protecting wetlands in water-scarce upstream countries that could help to protect flood-prone downstream countries. In politically difficult basin contexts, information and data sharing resulting from vulnerability assessments can also help to build trust and avoid misunderstanding between riparians.

Strategic adaptation planning has been emphasized by climate change scholars as an important factor for climate change adaptation (e.g., Füssel, 2007; Jacobs et al., 2018). Adaptation planning comes in various forms but can broadly be understood as actions and processes aiming to decrease vulnerability in response to actual and anticipated climatic changes to avoid or mitigate harm.

In the developing world two specific instruments were established under the United Nations Framework Convention on Climate Change to promote climate change adaptation: National Adaptation Programmes of Action and National Adaptation Plans. While these programmes focus on the most urgent adaptation needs of least developed countries and identify priority adaptation activities at the national level, these plans address more medium- and long-term adaptation needs. Although both of these have so far mainly been used to identify adaptation needs and to develop strategies at the national and sub-national level, they can also be used to foster more integrated regional adaptation planning – e.g., at the level of transboundary river basins (UNDP (United Nations Development Programme), 2009). Also, many developed countries have developed national (Australian Government, 2015) or regional (European Union, 2013) climate change adaptation plans.

Finally, *climate finance* has been argued to provide one potential means to access the necessary resources to realize adaptation activities at the national (Dellink et al., 2009; Steckel et al., 2017) and transboundary contexts (Blumstein, 2015; Schmeier, 2011; World Bank, 2019).³ Considering that funding for climate change adaptation in transboundary river basins, particularly in least developed countries, is limited, the international community has set up a broad-range of funding mechanisms for climate change adaptation. Several bilateral donors have developed mechanisms focusing specifically on climate change-related projects, including Germany's International Climate Initiative. Additionally, several multi-lateral funding mechanisms, such as the Global Environmental Facility's Least Developed Countries Fund and the Special Climate Change Fund, the Adaptation Fund, the Green Climate Fund or the World Bank's Cooperation in International Waters in Africa program,

have been set up. While these funds are generally designed to be accessed by individual states, most funding can also be used for transboundary river basin activities (World Bank, 2019).

The above outlined elements will now be examined through two case studies. Generally, few cases exist for such assessment as climate governance instruments have so far not been widely used in transboundary river basins. In the Orange-Senqu and Colorado basins, instruments can be examined and assessed to some extent as riparians in both basins employ such instruments to various degrees. Additionally, both river systems already experience high climatic variabilities, which are projected to intensify.

Because of the rather explorative character, the article does not follow a strict comparative design. Instead it aims to develop some initial ideas on how to employ traditional climate change governance instruments in a transboundary basin context to complement water governance approaches. Therefore, this study's objective is to inform the generation of hypotheses that can be tested in future research. The analysis is based on document analysis, primarily relying on the several water treaties governing both basins, policy and technical reports from river basin organizations, national climate change policy reports as well as semi-structured interviews.

Case study I: Colorado River Basin

Background

The Colorado River Basin is shared by the US and Mexico (Figure 2). The headwaters originate in the Rocky Mountains in the US. The basin spans seven western US states (Wyoming, Utah, Colorado, Arizona, California, Nevada and New Mexico) and terminates in the Gulf of California in Mexico, forming the border between the Mexican states of Sonora and Baja California. The US contains over 98% of the basin area and supplies nearly all the runoff (Transboundary Freshwater Dispute Database (TFDD), 2007). The basin is primarily fed by snowmelt, with 92% of its flow originating upstream of the Grand Canyon. It is also a highly regulated basin for hydropower and distribution, with large dams constructed throughout so that the basin's total artificial storage capability now exceeds four times its annual flow (Garrick, 2017). Between 70% to 80% of the basin's water in the U.S. is allocated for agriculture, with the balance being used for municipal, industrial, recreational, and other uses (Taylor et al., 2019).

The high regulation, reliance on snowmelt, population growth of areas supplied by the basin's waters, and current demand exceeding supply (Wildman & Forde, 2012) increase susceptibility to climate change. While climate models are inconclusive about the development of precipitation in the basin, they predict an average increase of temperatures that will likely result in decreases in annual flow (Milly & Dunne, 2020; Rajagopalan et al., 2009; Wildman & Forde, 2012). Consequentially, the severity of drought events is expected to increase. Droughts have already become a major problem in the lower basin states. A multi-year drought and decreasing river runoff have significantly diminished water levels of Lake Mead, a major drinking and irrigation water reservoir in Nevada and Arizona (Edalat & Stephen, 2019).



Figure 2. Colorado River Basin.

Water governance instruments

Several national and international agreements govern the allocation and management of the Colorado River Basin. The two most notable agreements include: 1) the 1922 Colorado River Compact between Lower Basin states (California, Arizona, and Nevada) and Upper Basin states (Colorado, Utah, Wyoming, and New Mexico); and 2) the 1944 US-Mexico treaty. Both agreements primarily focus on allocations. The 1944 agreement also provides the basis for the establishment of the International Boundary and Water Commission (IBWC). Both contain *flexibility mechanisms*. For instance, the 1922 Colorado River Compact, which addresses water allocation among the seven US states, allows for additional apportionment of consumptive use of water from the Upper Basin's allocations for the Lower Basin but does not directly address drought conditions. Article 10 of the 1944 agreement is more specific in referencing drought conditions, stating that water allotments to both countries can be proportionally reduced in the event of extraordinary drought (1944 Agreement, Art. 10). But the treaty is ambiguous about how water allocations would be determined in drought conditions.

The 1944 US-Mexico treaty also includes the possibility for amendments through a system of legally binding minutes. For example, 2012's Minute 319 established water conservation and drought measures for binational water management until 2017 (Sanchez & Cortez-Lara, 2015) through water conservation, infrastructure development, and environmental protection initiatives (Sanchez & Cortez-Lara, 2015). The two countries agreed upon Minute 323 in 2017, which focused on extending cooperative measures and adopting a binational water scarcity contingency plan for the basin. The Minute sets new *flexible allocation mechanisms* with quantities of flows distributed during times of high and low elevations at Lake Mead (IBWC (International Boundary and Water Commission), 2017).

Most efforts within the US to enhance supply and decrease consumption have occurred in the Lower Basin. No Upper Basin state has consumed close to its maximum allocated amount. It is unlikely that a sustained basin-wide drought would require reductions in consumptive use in Upper Basin states to meet its required deliveries to the Lower Basin (Wildman & Forde, 2012). Regardless, the flexibility mechanisms allowed through minutes could allow for better adaptability to increased variability.

Regarding *data and information exchange*, flow data is the only type of data that is shared and relevant to understand potential climate change impacts. The 1944 treaty sets a precedent by including provisions for sharing flow data. Subsequent agreements and minutes to the treaty also mention information exchange, including Minute 261 and agreements in 1983 and 1985 focusing on data exchange regarding water quality or pollution. Most data regarding the US portion of the Colorado River Basin is publicly available through state and federal websites, with data exchanges coordinated by IBWC. While data monitoring does not focus on climate change it has arguably played a role in facilitating current adaptation planning efforts (see below).

There have been no basin-wide initiatives that cover the *joint funding of adaptation activities*, but the US government has provided non-permanent funding to initiate this process. One example is the Pilot System Conservation Program, which began in 2014 to test conservation measures to boost reservoir levels in Lakes Mead and Powell. These programmes will keep approximately 76.5 MCM in Lake Mead at a cost of nearly US\$9.4 million (Baji & Ketellapper, 2017). In addition, Minute 323 dedicated funds from the US government towards conservation projects in Mexico that are expected to result in over 248 MCM of savings in exchange for a one-time water exchange for the US through December 2026 (IBWC (International Boundary and Water Commission), 2017). Combined, these conservation measures equal less than 2% of the Colorado's annual discharge. It is likely that measures like these will have to expand for increased resilience.

Climate governance perspective

Mexico's main national climate change policy is the General Law on Climate Change, adopted in 2012. It establishes the institutional and programmatic framework for national policy, but implications for water resources are mixed and mechanisms for implementation are unclear (Pittock, 2011). Mexico's National Water Commission (commonly known as CONAGUA) developed a National Drought Program in 2013. The programme aims to enhance forecasting, data dissemination as well as multi-level governmental coordination (Federman et al., 2014). The two basic elements include

prevention (monitoring-awareness, basin plans, evaluation and research), and mitigation or reactive attention (action during and after the drought) (Federman et al., 2014).

The US does not have an equivalent national climate change policy. Climate change is expected to particularly affect Lower Basin states through water shortages. Hence, Lower Basin states have developed adaptive planning and infrastructure mechanisms. Droughts may affect Arizona most acutely. This is due to Arizona's construction of the Central Arizona Project, a large system that supplies Arizona farms and major cities. Arizona and California agreed that all of California's water rights must be met before any further water (i.e. Arizona water rights established post-25 June 1929) is delivered to Arizona through the Central Arizona Project. Only 22.1% of the water rights in Arizona were established before that date, mostly belonging to irrigators, small cities along the Colorado River, and Native American reservations (USBR (United States Bureau of Reclamation), 2007). Lower Basin states have never received volumes below those promised for their consumptive use (Wildman & Forde, 2012). This has perhaps stifled more serious efforts in contingency planning due to a lack of volume restrictions.

Municipalities in Arizona and Nevada hold some of the most junior water rights in their states. Thus, they will be affected first by water shortages (Wildman & Forde, 2012) and have engaged in *adaptation planning*. Arizona has been storing unused water deliveries in a groundwater bank. After the bank empties, it can protect its urban population from shortages by reducing Central Arizona Project water deliveries to irrigators. Nevada has also been storing unused water in groundwater banks, which will yield up to 30,000 af/yr (0.037 km³) from separate banks in California and Arizona (Wildman & Forde, 2012).

Increasing demands, including those from Upper Basin states as they develop their allocated shares (Table 1), will mean less water available in storage (Fulp, 2005). As a response to the drought, the US Secretary of the Interior, in consultation with Basin states and other stakeholders, engaged in *adaptation planning* in 2007 by developing an interim plan for managing Lake Mead and Lake Powell, particularly for drought and low reservoir conditions through 2026 (Rajagopalan et al., 2009). These 'Interim Guidelines' include a shortage strategy and mechanisms to foster water conservation and water transfers in the Lower Basin.

The 2007 Interim Guidelines call for the US Bureau of Reclamation to reduce withdrawals, augment supply, and encourage conservation as Lake Mead drops, including reducing water available for consumptive use in the Lower Basin by varying amounts, delivering more water from Lake Powell to fill Lake Mead (Wildman & Forde, 2012), creating a system of intentionally created surplus designed to allow large Lower Basin

Table 1. Apportionment of Colorado River Basin water according to the 1922 Colorado River Compact and the 1944 U.S. Mexico Treaty.

Arizona	2.85 maf (3.515 km ³)	17.3%
California	4.40 maf (5.427 km ³)	26.7%
Colorado	3.86 maf (4.761 km ³)	23.4%
Nevada	0.30 maf (0.37 km ³)	1.8%
New Mexico	0.84 maf (1.036 km ³)	5.1%
Utah	1.71 maf (2.109 km ³)	10.4%
Wyoming	1.04 maf (1.283 km ³)	6.3%
Mexico	1.50 maf (1.85 km ³)	9.0%

users to augment system water with new sources, offsets, or intentional reductions in deliveries that are instead banked in the system for future use (Earle et al., 2015), and suspending previously negotiated guidelines that apply in times of surplus (Wildman & Forde, 2012).

The US and the US Bureau of Reclamation, building upon previous agreements, agreed to the new Upper and Lower Basin Drought Contingency Plans for the Colorado River Basin in 2019. The Upper Basin plan establishes a Demand Management Program for the Upper Basin through the authorization of storing conserved water in Lake Powell and coordinating Upper Basin reservoir operations to reduce lower elevations. The Lower Basin plan requires Lower Basin states to forgo deliveries beyond the levels agreed upon within the 2007 Interim Guidelines, further incentivizing voluntary conservation measures, and committing the US Department of Interior to conserve 100,000 acre-feet (123.35 MCM) (Stern, 2019). The US also has federal inter-agency coordinating groups that engage in adaptation planning (see Udall & McCabe, 2013). While these efforts will certainly improve adaptability in the short term, these plans fall short of what is projected to be needed for higher temperatures and more severe droughts.

Vulnerability assessments have not been conducted at a basin scale. However, the US Bureau of Reclamation, in collaboration with the seven Colorado River Basin states, completed a water demand and supply study for the US portion of the basin in 2012. The study was conducted in collaboration with stakeholders, including tribes, agricultural users, purveyors of municipal and industrial water, power users, and conservation and recreation groups (USBR, 2012). The study analysed future water supply and demand scenarios using hydrologic and climate modelling and detailed options and strategies to resolve future water supply and demand imbalances.

Case study II: Orange-Senqu River Basin

Background

The Orange-Senqu Basin (Figure 3) covers almost one million square kilometres and is shared between Lesotho, South Africa, Namibia and Botswana. It originates in the Lesotho Highlands and terminates in the Atlantic Ocean in Namibia. Despite its comparatively low runoff (11,500 million m³), the river basin's waters are highly utilized. South Africa particularly relies on the basin's water resources for commercial crop irrigation. The country accounts for over 90% of the total water use, which by far surpasses its own water supply to the basin (Lange et al., 2007; ORASECOM, 2013). Namibia and Lesotho also use the basin's water resources and Lesotho derives substantial royalties from water exports to South Africa through the Lesotho Highlands Water Project. Like the Colorado, the Orange-Senqu basin is highly regulated, containing more than 30 large dams and numerous intra- and inter-basin transfer schemes (ORASECOM, 2011).

Due to large water abstractions, less than half of the natural river runoff reaches the river mouth today, leaving only approximately 175 million m³ for additional consumptive allocations (ORASECOM, 2011, 2013). This poses a problem for the growing economies and environments of all four riparians.

Considering the high dependence of the riparian countries on the basin's water resources, changes in water resources availability due to climate change is highly relevant.



Figure 3. Orange-Senqu River Basin.

Climate change models predict an average increase in temperature between 1 and 2.5 degrees in the second half of this century. Precipitation is predicted to moderately decrease in most of the lower basin. Only parts of the upper basin, such as in Lesotho, will likely experience an increase in rainfall (Knoesen et al., 2009; ORASECOM, 2011). Because of these climatic changes, river runoff is also expected to change. While an increase of runoff is expected in the Lesotho part of the basin and parts of South Africa, tributaries in the rest of the Orange-Senqu are more likely to experience reductions. However, these runoff scenarios should be treated with caution as they are highly uncertain (ORASECOM, 2011).

The largely arid countries, Namibia and Botswana, have already experienced temperature increases in recent decades. Additionally, the lengths of dry periods have increased, augmenting the stresses on water resources (Batisani & Yarnal, 2010; Ministry of Tourism and the Environment of Namibia, 2008). Consequently, both countries are interested in increasing its use of Orange-Senqu water resources. Botswana has not historically utilized any of the river's resources and is therefore currently discussing an extension of the Lesotho Highlands Water Project to its territory with the other three riparian countries.

Water governance instruments

Several bilateral agreements and one basin-wide agreement govern the Orange-Senqu River Basin. The most relevant ones include (a) the Treaty on the Lesotho Highlands Water Project between Lesotho and South Africa from 1986, (b) the Agreement on the Establishment of a Permanent Water Commission between Namibia and South Africa from 1992 and (c) the Agreement on the Establishment of the Orange-Senqu River Commission (ORASECOM) between all four riparians from the year 2000. While the bilateral agreements primarily deal with issues of water allocation and the management of joint irrigation or infrastructure projects, the 2000 ORASECOM Agreement aims to

fulfil a basin-wide planning role, including such issues as water resource protection, development, and disaster management (Art. 5; ORASECOM Agreement, 2000).

All three agreements include *treaty flexibility mechanisms* that allow for amending treaties. The 1986 Agreement on the Lesotho Highlands Water Project additionally requires parties to review the treaty every 12 years (Art. 18; LHWP Treaty, 1986) and allows for amendment through a process of mutually agreed protocols. For example, Protocol VI to the agreement replaces the originally established Joint Permanent Technical Commission with the Lesotho Highlands Water Commission to extend beyond the narrow technical focus of the former by including environmental and socio-economic issues involved in running the Lesotho Highlands Water Project (Kistin & Ashton, 2008).

Only the treaty on the Lesotho Highlands Water Project contains a specific procedure for high and low flow events (Art. 7, 9, 14; LHWP Treaty, 1986). According to the agreement, Lesotho can, in the case of reservoirs reaching full storage capacities, exceed or, in the case of drought, decrease the agreed amount of water delivery to South Africa. In the latter case, Lesotho is required to recoup the amount of water through higher deliveries in the following six months. Although the agreements on the Permanent Water Commission and ORASECOM allow both basin organizations to advise the parties to the agreement on the establishment of specific drought (and in the case of ORASECOM on flood) mechanisms, no specific provisions have been set up for either treaty. This is particularly noteworthy as the river basin is regularly affected by flood and drought events.

As to the *sharing and generation of data and information* on the river basin a lot of hydrological knowledge has been continuously collected – primarily because of the high utilization of water resources. ORASECOM plays a key role regarding data and information on climate change and its impacts on the river basin. The river basin organization has engaged in conducting and commissioning many scientific studies. Some of these directly relate to climate change and the expected impacts on the river basin, including a study downscaling global climate change models for the Orange-Senqu basin (ORASECOM, 2011). The commission also initiated a water quality monitoring programme, which has included regular basin-wide water quality surveys since 2010 (ORASECOM, 2010). Although this monitoring programme does not have a specific climate change focus, the monitored parameters can serve as important indicators for observing the impacts of climate change at the river basin level.

The *funding of river basin adaptation activities* implemented in the Orange-Senqu basin is provided through direct contributions from national budgets, membership contributions to a river basin organization that then realizes activities (such as ORASECOM), or through donor funding. Adaptation-relevant programmes at the basin level, such as the climate change study mentioned above or the water quality monitoring programme, have been financed by bilateral or multilateral donor actors (see Blumstein, 2017), including Germany, UK, Australia, and the European Union.

Climate governance perspective

Although climate change generally receives a lot of attention in the region (see Earle et al., 2015) there has been no use of climate change tools at the basin level. Neither a *vulnerability assessment* nor *climate change adaptation planning* have been realized for the Orange-Senqu Basin so far. That said, it needs to be acknowledged that the aforementioned climate change

modelling study also provides insights into vulnerabilities of different sectors (including agriculture, health, water and sanitation and biodiversity) and outlines some potential adaptive responses. For example, the study outlines that because of an increasingly hotter and drier climate in the lower basin, irrigation requirements are likely to increase. In the upper basin, higher rainfall and floods could result in higher rates of erosion, which would also affect downstream riparians.

While coordination of climate change adaptation at the river basin level is absent so far, the four basin countries have been developing different climate change policies and adaptation plans at the national levels.

Namibia has conducted a Climate Change Vulnerability and Adaptation Assessment (2008) as well as a National Policy on Climate Change (2010). The documents outline that Namibia expects the impacts of climate change on its water resources to affect variability and decrease the overall amount of available water, which is one of the main constraints to socio-economic development.

As the only least developed country in the Orange-Senqu Basin, Lesotho has developed a National Adaptation Programme of Action (2007). The programme describes expected impacts of climate change and outlines prioritized adaptation activities to respond to those impacts. This includes wetland conservation and reforestation to decrease soil erosion and the construction of water conservation/collection dams to decrease vulnerability to floods. The document, however, makes no reference to the transboundary level – such as potential impacts of national adaptive responses to downstream riparians.

South Africa has developed a National Adaptation Strategy (2016) that identifies vulnerabilities and adaptation activities of a broad range of sectors, including water. In the strategy, South Africa recognizes the importance of transboundary water cooperation and outlines that it will strive towards transboundary agreements that enable adaptive responses and cooperation. However, the strategy does not name the nature or specific content of such adaptive responses. An important instrument for managing the various water infrastructures and to ensure current and future water supply are so-called Reconciliation Studies that have been developed for all major water bodies, including the Orange-Senqu River Basin (Department of Water Affairs: Republic of South Africa (DWA), 2014). The reconciliation strategy for the Orange-Senqu River Basin contains several intervention scenarios outlining possible solutions to ensure sufficient water supply for the future (up to 2050). While variability and adaptation are naturally part of such a strategy, it does not specifically consider climate change, which is likely to increase already existing variabilities in water availability.

Botswana has been in the process of developing a National Climate Change Strategy and Action Plan for some time, which, among other things, includes the development of water resources infrastructure (Earle et al., 2015). In its Integrated Water Resources Management & Water Efficiency Plan (2013), Botswana identifies climate change as a major cross-cutting issue affecting water resources and water management of the country. The plan furthermore underlines that Botswana will increasingly need to rely on shared water resources and emphasizes the need to build additional water storage opportunities to adapt to climate change. The plan also mentions the possibility of transferring water from the upper Orange-Senqu as a possible alternative to augmenting the North-South Carrier from the Zambezi River. Although Botswana's share of the basin is very small, the river system is considered highly important for Botswana's water security and long-term adaptation to climate change.

Botswana, in coordination with the three other riparians (through ORASECOM), is currently conducting a feasibility study to determine the viability of water resource development options for Botswana to access water from the Lesotho Highlands (Government of the Republic of Botswana, 2013; ORASECOM, 2018).

An important factor to consider for climate change resilience in water management is the large number of storage and water transfer systems in the Orange-Senqu Basin. While the basin-wide organization of ORASECOM could, potentially, provide a coordination role, it has not fulfilled this role so far. This can partly be explained by the fact that the ORASECOM Agreement gives precedence to the pre-existing transboundary water treaties and the respective basin organizations that deal with water allocation and infrastructure aspects. The absence of such coordination, however, limits reliable adaptation planning for downstream riparians Namibia and Botswana. Both countries use very small amounts of water today but need additional water resources to adapt to an increasingly drier climate.

Finally, regarding the use of international climate finance, ORASECOM is currently in the process of developing a Climate Resilient Water Resources Investment Strategy, funded by the African Development Bank (Africa Water Facility) and the NEPAD Infrastructure Project Preparation Facility, two of the major regional funds that are relevant for transboundary basin adaptation. The objective of the strategy is to increase climate adaptation funding for a range of priority projects in the basin and to conduct pre-feasibility studies on the Lesotho-Botswana Water Transfer Project mentioned above.

Discussion

Both river basins examined in this paper are confronted with climate variabilities and expect long-term climatic changes. A closer analysis reveals that while water governance mechanisms introduced in the introductory section are employed and relevant to climate change adaptation there is yet little use of climate change adaptation tools.

Regarding water governance instruments, we find that both cases contain *flexible treaty mechanisms*, which allow the incorporation of climate change. However, in the Colorado River Basin, recent efforts, such as the Interim Guidelines and the 2019 Drought Contingency Plans, have not eased concerns about delivering Colorado River water at current rates in the long-term. Many US lawmakers reportedly acknowledge that both plans are inadequate to address climate change's harmful impacts on the region's environment and economies (Nicla, 2019).

Data and information sharing/generation is happening in both cases – particularly with climate change data, the Orange-Senqu is engaging in climate modelling in a basin-wide capacity, while the Colorado has yet to engage in such a task in a binational manner. But, scientists in the US have completed an “Assessment of Climate Change in the Southwest United States” (Garfin et al., 2013). In the Orange-Senqu River Basin the exchange of data and the joint acquisition of basin data through the basin monitoring programme of the regional river basin organization arguably helped to improve mutual understanding and trust. Although Botswana is in a much weaker socioeconomic and political position within the basin, all riparians jointly agreed to extend the Lesotho Highlands transfer scheme to supply water to Botswana, which is increasingly facing water insecurity because of (amongst others) climatic changes.

Regarding the sustainable *funding of adaptation activities*, we find that in the case of the Orange-Senqu Basin funding for adaptation activities so far exclusively relies on external donors. While it is very likely that external donor funding has crucially funded relevant adaptation activities, solely relying on external donor funding could also pose a challenge regarding the long-term availability and hence sustainability of funding of adaptation. Within the Colorado River Basin, funding for adaptation activities has occurred within the US but concerted efforts to fund binational sustainable activities have not occurred until just recently with Minute 323's funding of conservation mechanisms in Mexico.

Concerning climate change governance instruments, we find that although climate change adaptation plays a role at national and sub-national discourses/activities it is not (yet) a central element in regional cross-border cooperation. As such there is also only limited experience in both cases regarding the analysed climate change instruments, including *vulnerability assessments*, *adaptation planning* and only some experience with using *climate finance* in the case of the Orange-Senqu River. These instruments nonetheless harbour potential to enhance transboundary climate change adaptation. As the Orange-Senqu River Basin exemplifies, the adaptive responses to climate change upstream can affect the ability to respond to increasing climatic vulnerabilities downstream. A more coordinated approach to adaptation that considers the possible negative effects on other riparians and identifies synergies could increase overall effectiveness of climate change adaptation. Although extending adaptation planning to the regional level may overwhelm national actors from a capacity and perspective, failing to account for transboundary consequences of adaptation interventions can strain inter-riparian relations and increase the risk of water-related disputes. There could hence be room to learn from other transboundary vulnerability studies (such as in the Nile and Neman River Basin) or where adaptation planning has been coordinated between riparian countries (e.g., in the Niger River Basin).

National Adaptation Plans particularly could be a tool for enhancing transboundary activities for climate change adaptation. Guidance could be provided by the Adaptation Committee of the United Nations Framework Convention on Climate Change (see Nadin & Roberts, 2018).

Lastly, available *climate finance* has been used in the Orange-Senqu Basin where ORASECOM is in the process of developing a Climate Resilient Water Resources Investment Strategy with funding from African Development Bank and New Partnership for Africa's Development. The case exemplifies that a river basin organization can play an important role in mobilizing climate funding for adaptation activities within internationally shared basins. Cooperating with a regional organization like ORASECOM can be more attractive to international financiers as this will lower administration costs (compared to financing multiple smaller projects and dealing with multiple actors).

Climate funding is still infrequently used in the context of transboundary rivers. This could be due to the fact that providing funding for regional and basin scale activities is not often a priority of climate funding mechanisms and fund accessibility for regional (transboundary) organizations often remains difficult (World Bank, 2019). To access funding also often requires accreditation for which a basin organization needs to meet a variety of standards regarding legal status, financial and management integrity, institutional capacity, transparency, self-investigation and corruption. These standards can make it difficult for a regional water institution to become accredited.

Conclusions

Many transboundary river basins face tremendous climate-related challenges. This article therefore analysed the potential to strengthen adaptation to climate change in these basins by complementing water governance instruments with climate policy instruments. We identified and examined six instruments through a case-study analysis of two basins: The Orange-Senqu and the Colorado. We find that the evidence for water governance instruments is much stronger in both cases while the examined water policy instruments have been applied to a much lesser degree.

It should be noted that our instrument selection was somewhat subjective and is based on past on-the-ground experiences. Also, the instruments are analysed within this paper at a national and basin-wide scale. This level of analysis can overlook climate adaptations happening at smaller scales. The selection of instruments does therefore not claim to be comprehensive. Future research should look at other adaptation variables and empirical cases that gained experience with vulnerability assessments and adaptation planning to obtain a better understanding of the role of such mechanisms.

Notes

1. One can generally observe that while water governance scholars and policy actors have embraced climate change research into their research agendas, climate change researchers often do not pay particular attention to water issues. One implicit objective of this paper therefore is to encourage climate change research that emphasizes to put greater emphasis on water issues.
2. While the origins of vulnerability concepts are found in the hazards-risk literature, vulnerability today is a central concept in climate change research. The most influential definition for vulnerability in the climate change literature, is the definition provided by the Intergovernmental Panel on Climate Change (IPCC) which defines vulnerability as: '[...] the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity' (IPCC, 2001, 995).
3. Climate finance is public and private sector funding allocated to projects that address climate change, including mitigation as well as adaptation efforts (World Bank, 2019). In the context of this paper, we only consider funding that is provided for adaptation activities.

Disclosure statement

No potential conflict of interest was reported by the authors.

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