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Climate change and its impacts on hydro-politics in transboundary basins: a case study of the Orange-Senqu River basin

S. K. Mgquba and S. Majozi

ABSTRACT

In any basin or basin country, water security is of critical importance. The increase in populations and water demand are placing stress on the available water resources. This is likely to become more complicated within shared water-courses. Issues of equitable water allocation and distribution are important for all countries involved. Fostering cooperation and managing conflict hence become fundamental in transboundary water management. Climate change is likely to add new challenges to pre-existing dynamics in transboundary systems. According to the Southern African Development Community (SADC) Climate Change Strategy and the SADC Shared Watercourses Protocol, there is a need to integrate climate change impacts and associated adaptation measures into water management plans to ensure water security for all countries involved in the future. The Orange-Senqu basin, which spans over Lesotho, South Africa, Namibia and Botswana, will be used as a case study to closely examine and reflect on some hydro-political challenges that may be brought about by climate change-associated impacts within the basin states. Although uncertain, climate projections largely indicate decline in rainfall and increase in temperature, especially within the South Africa part of the basin. This inherently is bound to affect water quantity and, therefore, availability within the riparian states below South Africa.

Key words | climate change, hydro-politics, risk and vulnerability, transboundary, water availability

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INTRODUCTION

When basins encompass multiple states, the utmost concern is how to design and sustain institutions to equitably share and manage the water resources (Earle 2005). An extraordinary number of multilateral agreements designed to promote cooperation over international rivers have been drafted and signed over the course of the 20th century (Cooley & Gleick 2011; Gerlak & Scheier 2014). In transboundary and shared watercourses it is important to establish a common working ground, understanding the needs of all the riparian states. Water is a limited resource, especially in Africa, and this therefore places emphasis on the necessity of formal transboundary agreements (Earle 2005; Sneddon & Fox 2006; Gerlak & Scheier 2014). Between Wolf *et al.* (2003) and Turton (2005a, 2010) there is a general consensus on the six leading transboundary basins in the Southern African Development Community (SADC) region, namely, the Incomati, Cunene, Limpopo, Zambezi, Okavango-Makgadikgadi and the Orange-Senqu River basin, which serve as examples of multilateral agreements.

In hydro-politics, water is regarded as an economic good and human right and therefore it brings issues of social and economic development of riparian states to the forefront. Loosely defined, hydro-politics is a term used to describe

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the socio-political dynamics in water-related matters. The Unrepresented Nations and Peoples Organization highlights that human rights are the centre of water resource allocation and access (Jankielsohn 2012). Easton (1965) and Turton & Henwood (2002) define hydro-politics as the authoritative allocation of values in society with respect to water. Water is an essential natural resource for basic human life and hence its provision is central to all societies, to be used for industrial, domestic and environmental purposes. The scarcity of water resources across the African continent has been highlighted by various authors (Earle 2005; Hellberg 2005; Turton 2005a; Heikkila *et al.* 2014) with emphasis on eight out of 17 international basins identified as being at risk being found in Africa. Six of those transboundary basins are found in the SADC region. According to Turton (2005a), this is starting to suggest that water is fast becoming a commodity in the African continent.

Recognizing water and its importance as an economic good is crucial, and as such, careful attention has to be given to the nature in which it is used and how it is prioritized for economic growth and development, especially in developing nations such as those in Southern Africa (Turton & Henwood 2002; Earle 2005). The economy of African countries relies greatly on primary economic activities, thus great emphasis is placed on water extractive industries such as mining, forestry and irrigated agriculture for food production (Earle 2005; Cooley & Gleick 2011). It is important to find a balance between water used for economic growth as well as for other activities so as to ensure that water is available for social and environmental use. Social resources comprising well-organized structures and institutions are an important factor as they create an enabling environment putting in place government systems, laws and legislation to help development and build institutional capacity in order for proper efforts to be made to minimize hydro-political vulnerability, effectively manage water resources and avoid conflict (Hellberg 2005; Cooley & Gleick 2011).

This paper tries to analyse the hydro-politics that might arise within a basin as a result of impacts associated with climate change. The first question will address how hydro-politics functions in African transboundary systems, and the second question will study how the impacts of climate change are likely to alter the existing hydro-political landscape, giving a special focus to the Orange-Senqu basin states. To answer and provide better understanding of the vulnerability and threats posed by climate change to this critical transboundary system and how these changes stand to alter the hydro-politics in the basin, the DPSIR framework was used to analyse the water resources in the Orange-Senqu River basin. This was achieved by identifying five key elements in each riparian state as outlined by the framework; namely, the drivers, pressures, state, impacts and responses to climate change. From the information gathered, a thorough and robust analysis is made, highlighting areas of concern that require careful consideration within the hydro-political context of the Orange-Senqu basin.

BACKGROUND TO THE ORANGE-SENQU BASIN

Transboundary water systems across the world are an important source of water for multiple purposes; namely, social, economic and industrial and environmental uses (Turton 2005a). Transboundary river systems are often important sources of water for the riparian countries, providing water for hydropower, irrigation supplies, species habitat and fisheries (Cooley & Gleick 2011; Heikkila *et al.* 2014) such as in the case of the Orange-Senqu basin. Many of the world's transboundary river basins are simultaneously perceived as important engines of regional economic development, as crucial bases of livelihood resources, and as critical sites of biodiversity conservation (Turton 2005a). This highlights the significance of shared water resources and emphasizes the need for compromise and the establishment of good governance practices to ensure appropriate allocation and proper management of the resource.

The Orange River basin has a total basin area of 964,000 km^2 with a mean annual runoff (MAR) of $11{,}200 \times 10^6\ m^3$. As shown in Figure 1, there are four riparian states, with 4% of the basin area lying in Lesotho (upstream riparian and an impacted state), 62% in South Africa (a pivotal state), 9% lying in Botswana (a pivotal state) and 25% in Namibia (downstream riparian and a pivotal state). Contribution to MAR by each riparian is unequally distributed, with 55% coming from South Africa, 0% coming from Botswana, 41% coming from Lesotho and 4% coming from Namibia (Kranz *et al.* 2005; Turton 2005a).

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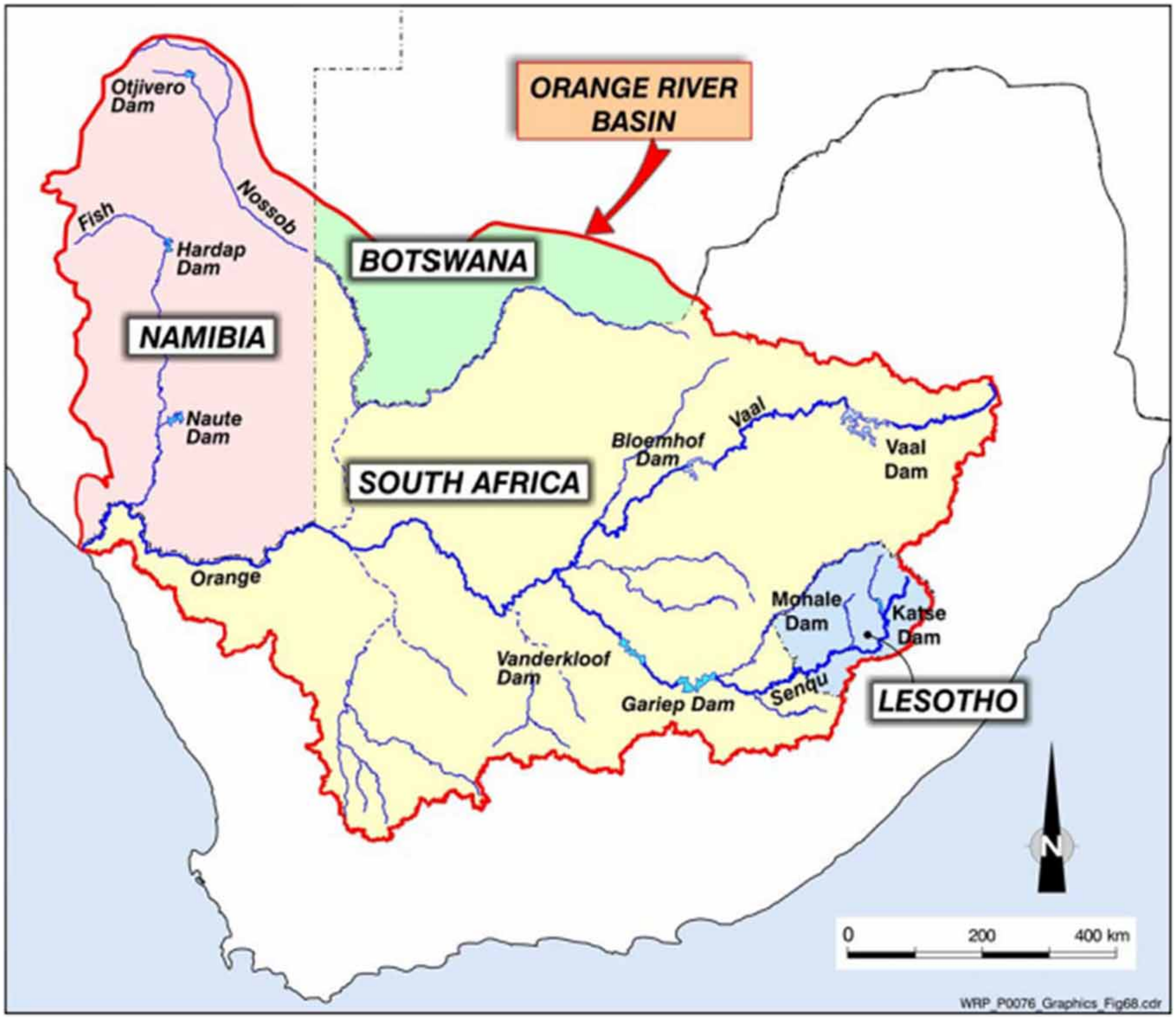

Figure 1 | Orange-Senqu River basin and its riparian states showing major dams (*Source:* ORASECOM 2007).

The Orange River basin is the most developed of all the rivers in Southern Africa, with at least 29 dams having a storage capacity of more than $12 \times 10^6\,m^3$ (24 in South Africa and five in Namibia) (Kranz *et al.* 2005; Kellar 2012). The largest of these are the Gariep Dam, with a storage capacity of $5{,}600 \times 10^6\,m^3$ and the Vanderkloof Dam, with a storage capacity of $3{,}200 \times 10^6\,m^3$, both of which are in South Africa (Kranz *et al.* 2005). It is evident that the Orange River basin is the largest of all the international river basins in South Africa, both in terms of physical size, and in terms of the volume of MAR involved. The importance of this river basin is also evident, because the Orange is a recipient basin for three inter-basin transfers (IBTs), and a donor basin for three IBTs and four intra-basin transfers also in existence.

The Vaal River basin can be regarded as a sub-basin within the Orange River basin, and all the water used in Gauteng is provided by the Vaal River basin (Turton 2005a). The Orange River carries 20% of the total river flow in South Africa, with the Vaal River being an important tributary of the system. Gauteng Province is 100% reliant on IBT water, channelled through the Vaal River system, illustrating the strategic importance of the Orange River basin. Given the heavy reliance of the South African national economy on water from this particular basin, governance of water resources needs to make careful consideration and understand the risks posed by climate change as well as how the different needs of the riparian states will be affected. This sub-basin is of significance because its water supports 40%

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of the South African population, creates 50% of the country's wealth and generates 85% of the electricity in the entire country. In addition to this, 10% of Africa's economic output is produced from the Vaal sub-basin. In order to support this economic activity, the Vaal sub-basin has links to eight other river basins in a complex arrangement of IBTs that range from the Limpopo in the north to the Sundays in the south (Heyns 1995). In the Vaal basin, much of the water returns to the Orange River as treated effluent, which is available for downstream users (Turton 2005a). The fact that Gauteng is totally reliant on water from IBTs makes the Orange River basin of great economic and strategic importance (Kellar 2012). In an assessment of international river basins at risk of future water conflict, Wolf *et al.* (2003) suggested that the Orange-Senqu basin has the potential for political stresses or conflicting interests in the coming 5–10 years (2005–2010). Other basins at risk that were identified in the study include: the Ganges–Brahmaputra, Han, Incomati, Kunene, Kura-Araks, Lake Chad, La Plata, Lempa, Limpopo, Mekong, Ob (Ertis), Okavango, Orange as well as Aral, Jordan, Nile and Tigris–Euphrates, which were also under dispute.

Although the countries making up the Orange-Senqu basin have similar arid to semi-arid characteristics, the climate and aridity varies across the basin from east to west with an average rainfall of 330–400 mm/yr ranging from <50 mm/yr in arid regions of Namibia to >2,000 mm/yr in the high rainfall mountainous areas of South Africa (Knoesen *et al.* 2009). The annual water demand and use is shared among agriculture (64%), urban supply (23%), mining (7%) and rural supply (6%) (Knoesen *et al.* 2009). The difference in rainfall between the countries as a result of natural climate variability sets the premise for conflict; however, the establishment of the Orange-Senqu River Commision (ORASECOM) Agreement in 2000 recognized this inherent variability and pursued forming a multilateral basin-wide agreement between all riparian states to better govern the shared water resource (Turton 2005b).

ORASECOM was the fourth basin-wide regime formed in Southern Africa under the SADC Protocol on Shared Watercourse Systems (Turton 2005b; Knoesen *et al.* 2009). A significant hydro-political aspect of the ORASECOM Agreement is the fact that Botswana is a recognized riparian state, even though it contributes no stream flow and makes no use of the surface water from the Orange River (Turton 2005b). This gives Botswana a wider range of diplomatic options by allowing concessions to be granted to other riparian states in return for political support in River Basin Commissions where they have a greater strategic interest, such as in the Limpopo and Okavango basins. This also puts Botswana at the equilibrium of political power in ORASECOM, with bargaining positions either in support of Namibia (in return for concessions elsewhere, such as in the Okavango and Zambezi River basins), or in support of Lesotho (Turton 2005b).

The second key factor that may lead to hydro-political vulnerability in this basin is intensive infrastructure. In the case of the Orange-Senqu basin, with a total 29 dams, careful thought must be given to the construction of a dam in an upstream country as it can reduce the amount of water flowing into the downstream countries. It is therefore crucial to establish an agreement regarding the sustainable natural flows for riparian countries in order to minimize conflict (Earle 2005). This is reflected in the Upper Basin Agreement of the ORASCOM Agreement between South Africa and Lesotho. The Lesotho Highlands Water Project (LHWP), for example, has four protocols covering in detail aspects of dam design, dam construction, operation and maintenance of the hydro-power station, and the institutional arrangements needed to manage such a complex project. The LHWP Treaty is the most comprehensive in existence in the Southern African water sector, which is due to its strategic economic importance for both Lesotho and South Africa (Turton 2005b).

In the Orange-Senqu River basin, the economic value of water is demonstrated in the LHWP because it is of great importance to South Africa as it delivers water to the Gauteng region. Gauteng accounts for approximately 60% of South Africa's GDP and 40% of its urban population. The agreement put in place ensures that South Africa gets water for industrial use while electricity is generated for Lesotho. Although Namibia and Botswana are excluded from LHWP, under the ORASECOM Agreement water for industrial and economic use is ensured to be allocated accordingly. The ORASECOM Agreement also considers the importance of the basin as a vital source of water for the three most developed countries in the southern hemisphere. Beyond being the sole source of water for Gauteng,

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it is extremely important to Namibia as it contains more than five dams with a capacity of 452×10^6 m^3 on which Namibia relies heavily for its economic growth and development. Furthermore, Botswana's economic hub is located in Gaborone, which at times is supplied with water from Lesotho via an IBT from South Africa (Turton 2005b).

HYDRO-POLITICS: A SEARCH FOR A DEFINITION

The management of transboundary river systems brings challenges which cause conflict between the riparian states (Wolf *et al.* 2003; Earle 2005). This stems from the fact that a number of international basins inherit a history of social and political backgrounds which differ between riparian countries and that need to be addressed in order to minimize conflict and establish a level of compromise (Earle 2005). These differences introduce what is called hydro-politics. The definition of hydro-politics is highly debated among various authors as there is a difference of opinions regarding key factors at the centre of the matter. Hydro-politics is defined as the systematic analysis of interstate conflicts and cooperation in relation to international water resources (Hellberg 2005; Menga 2016). Meissner (2001) views hydro-politics as the systematic investigation of the interaction between states, non-state actors and other participants, such as individuals in relation to the authoritative allocation and/or use of international as well as national water resources. Hydro-politics, coined by Waterbury (1979), is the potential for conflict and violence to erupt over international waters. Hydro-politics also relates to the ability of geopolitical institutions to manage shared water resources in a politically sustainable manner; that is, without tensions and conflicts between political entities (UNEP 2007).

Earle (2005) relates to two key factors which contribute to chance or vulnerability of conflict when analysing the hydro-politics of a country or basin. These are: first, the rate of change in the hydrologic system and second, the institutional and legal capacity for a country or basin to address such changes. It is hypothesized that if the capacity to absorb change is sufficient to respond to the occurring change, the vulnerability for conflict is minimized (Earle 2005). According to UNEP (2009), water resources vulnerability can be described as the characteristics of the water resources system's weakness that disrupt the functionality and operations of the system when there is social and environmental change. Simply put, it is the sensitivity of the system to potential threats and its ability to cope with the external pressure. Water resources vulnerability can be measured as the exposure of a water resources system to stressors at the river basin scale, and the capacity of the ecosystem and society to cope with the threats to the healthy functionality of a water system (UNEP 2009).

The combination of these two factors, that is, the rate of change and institutional capacity, characterizes the context in which the water is managed, meaning that water management challenges are either dealt with in a politicized or securitized manner. Politicization refers to the action of making an issue or event become political in its nature. In the context of hydro-politics and transboundary systems, politicization means to make a water management issue open and something that is discussed and decided upon in a political setting which is open to the normal haggling of politics (Earle 2005). Hydro-political vulnerability is defined by the risk of political dispute over shared water systems (UNEP 2007). Wolf *et al.* (2003) describes the relationship between environmental change, institutions, and hydro-political vulnerability as 'The likelihood of conflict that rises as the rate of change within the basin exceeds the institutional capacity to absorb that change' (UNEP 2007). The relationship described by Wolf *et al.* (2003) makes similar reference to two elements highlighted in the description of hydro-politics, which are the hydrologic change experienced by a system and the ability or capacity for the system to absorb and cope with that change. Earle (2005) suggests that when analysing the state of hydro-political vulnerability in Southern Africa it is important to study the landscape from both perspectives; that is, to understand the underlying factors creating the vulnerability to conflict as a response to the hydrologic change in the system as well as the legal and institutional response to the change.

The key issues causing hydro-political vulnerability in Southern Africa include natural climatic variability, intensive infrastructure, population dynamics, economic priorities and social resources (Earle 2005; Cooley & Gleick 2011). Natural climate variability looks at the inherent variability in the general climatic and weather patterns of a region

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such as the changes in rainfall, which may be characterized by frequent floods or droughts, consequently impacting on the amount of water available. The natural climate of the SADC region is characterized by arid to semi-arid conditions as many countries receive mean annual rainfall that is far less than the world average, which begins to indicate the limited water availability and sets the scene for hydro-politics in the region (UNEP 2007).

Another key factor causing hydro-political vulnerability is industrialization. Industrialization in many instances translates to increased water abstractions to help grow the economy, especially in developing countries. Managing water as an economic good is important for achieving efficient and equitable use, and for encouraging conservation and protection of water resources (Hellberg 2005). Asymmetric economic growth can cause tensions between riparian states due to the disproportional use of water. This is why managing water as an economic good is important, so that any development or water extractive activity is managed using the participatory approach involving all planners, stakeholders and policy-makers for the equitable and efficient use of water in order for all parties to reach a level of compromise and avoid conflict (Hellberg 2005). According to UNEP (2007), having major independent development projects running simultaneously in riparian states can be strenuous on the water resource, causing tension and giving rise to disputes over the shared resource. Thus, positive political relations and the undertaking of collaborative projects are advocated. The growth or decline in population determines the water needed in a region. Population dynamics become challenging in regions where there is diminishing water resource due to water scarcity and a continuous rise in population (Earle 2005).

General hostile conditions between riparian states together with the absence of institutional capacity causes high hydro-political vulnerability especially in countries of low economic development, which are most vulnerable to climate change impacts, such as those in the SADC region. Political will from riparian states sets a premise for the establishment of legal frameworks and agreements in the joint management of the water resource, creating an enabling environment for a level of compromise to be reached and conflict minimized (UNEP 2009). The dependency on the water resources from all riparian countries showcases

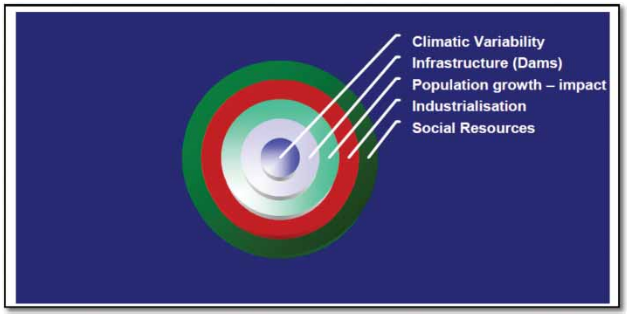

Figure 2 | Key issues causing hydro-political vulnerability (*Source:* Earle 2005).

complexities within the Orange-Senqu basin; hence, the need for adequate and proper institutional capacity which anticipates abrupt and unexpected changes in the basin and puts in place appropriate mechanisms and management systems that will assist in dealing with any change, thus ensuring that all riparian states are always prepared (Kellar 2012).

Figure 2 shows the five factors that contribute to and cause hydro-political vulnerability; that is, the risk of political dispute over a shared water resource. This diagram relates each factor and demonstrates how each of the factors influences the others, with climate variability as the core component while social resources encompasses the other four factors. Climate variability is the primary cause of hydro-political vulnerability because changes in rainfall patterns and temperature will alter the temporal and spatial distribution of rainfall and change the evaporation rates, which will have an impact on the water resource available. This may have knock on effects and impacts on the infrastructural sector and may call for response measures such as the construction of additional dams to deliver more water for the growing population and provide water for demanding economic activities. All this is governed and controlled by the water management policies enforced by government and legal institutions, which represent the social resources of a region (Earle 2005).

CLIMATE CHANGE AND CLIMATE VARIABILITY: WHAT DOES IT MEAN FOR BASIN STATES?

While Africa is well endowed with minerals, water remains a fundamental constraint to economic growth and development

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and a major factor in the hydro-political context (Turton 2010). These often competing roles make governance particularly challenging, hence hydro-politics needs to be addressed. Climate change projections are likely to have multiple impacts on the Orange-Senqu River basin, particularly when temperature increases are coupled with rainfall decreases (ORASECOM 2014). Investigations from the literature show that each basin state will be faced with a number of impacts, hazards and risks in one way or another.

Climate features of each region

The four basin states (South Africa, Lesotho, Botswana and Namibia) making up the Orange-Senqu are characterized by unique weather and climatic patterns that ultimately determine the yield of the basin. Runoff generated from South Africa and Lesotho significantly contributes to the water available in the Orange-Senqu basin (Turton 2005a).

South Africa is a semi-arid country with the characteristic of highly variable rainfall, which is unevenly distributed across the country from a moist wet climate in the east to becoming dry extending to the west. South Africa's rainfall varies with altitude from a mean annual precipitation (MAP) of 250 mm at low altitudes to a peak MAP of 2,000 mm at the top of the Drakensberg escarpment where the altitude is approximately 2,800–3,000 m above sea level (Nel & Sunmer 2006). There is a marked gradient of precipitation in South Africa, with high rainfall in the north and declining towards the south, and a similar trend is observed from east to west. Thus, the rainfall is concentrated along the escarpment on the east, which receives orographic rainfall from the warm ocean current. The Drakensberg escarpment, which is shared with Lesotho, is regarded as the water tower for the country as runoff generated from the mountain provides water for Gauteng and KwaZulu-Natal provinces. The mountain range is of crucial importance to both countries because it is of social and economic significance. The average rainfall is 497 mm compared to the world average of 860 mm, and this is unevenly distributed with 65% of the country receiving less than 500 mm and 21% receiving less than 200 mm annually (Turton 2005a).

Lesotho is a landlocked country surrounded by South Africa and dominated by the Maloti and Drakensberg mountain ranges. Lesotho has a semi-arid to arid climate. An estimated 85% of the population lives in rural areas and depends on subsistence farming and dryland agriculture for livelihood. This leaves a majority of the country under threat and vulnerable to climate change because communities do not have adequate capacities to adapt and live under the harsh conditions brought by climate change and variability. Lesotho has a continental temperate climate with well-marked seasons of spring, summer, autumn and winter. The average temperature ranges between $-2\,^{\circ}$C in winter and 28 °C in summer. Heavy frost is frequent, particularly in the mountain region, and determines the length of the summer growing season. Precipitation varies from 450 mm per annum in the Senqu River valley and the southern lowland districts to over 1,300 mm per annum in the northeast of the Drakensberg Mountains (Lewis & Oosthuizen 2014).

Botswana is a landlocked arid to semi-arid country with unevenly distributed and highly unreliable rainfall ranging from 250 mm to 650 mm. Botswana is situated in the catchment basins of the Limpopo, Okavango, Orange and Zambezi rivers, all of which are shared with other countries. About two-thirds of the country is covered by the Kalahari Desert sands and is not suitable for agricultural production. Botswana's climate is influenced by La Niña and El Niño, making it vulnerable to seasonal variation. Water resources in Botswana can be described as impermanent or momentary, meaning that they are available for a short space of time and because of low rainfall and surface water being lost through high evaporation rate and seepage from the sandy soils (BECCA 2008).

Namibia is situated on the south-western coast of Africa. Namibia experiences a hot dry climate with sparse and irregular rainfall. Ninety-two per cent of the of the country is classified as either semi-arid, arid or hyper-arid with mean annual temperatures ranging from 16 °C along the southern coast, between 20 °C and 22 °C in large parts of the country's interior and the eastern parts, and above 22 °C in the north. Mean annual rainfall is less than 250 mm with an upper limit of about 600 mm per year; however, rainfall is extremely sparse and variable such that parameters such as mean and median cannot be used to describe the rainfall for the country. Of the total rainfall, 83% is lost to evaporation, 14% is consumed by vegetation, 2% becomes runoff and is captured and accessed from surface storage facilities

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and 1% is used for groundwater recharges (MET 2010). In the arid coastal region another source of moisture is advective fog, which is experienced for approximately 146 days per year and exceeds rainfall.

Climate change and projections of the basin states

The evidence of climate change and its impacts have begun to be felt in South Africa, with observed changes in temperature and rainfall. Kruger & Sekele (2013) indicate positive trends in the average annual, maximum and minimum temperatures as well as an increase in the number of hot days and nights, and a decrease in the number of days with low temperatures, indicating a decrease in the diurnal range. Regional studies conducted by Kruger & Shongwe (2004) and Tshiala *et al.* (2011) support the positive trends, also detecting an increasing trend of 0.12 °C in the average annual temperature of 30 catchments in Limpopo for the period 1950–1999. For South Africa, Mason & Jury (1997) reported a decrease in mean annual rainfall for the eastern lowveld, as well as an increasing trend in rainfall variability. Similarly, Kalumba *et al.* (2013) showed increasing inter-annual rainfall variability across South Africa. These studies attest to climate change and impacts on the temperature and rainfall regime as we know them (Figures 3 and 4 give an example). Climate change projections indicate that South Africa will experience more rainfall variability, meaning that floods may become intense and severe droughts are likely to be experienced, consequently leading to more arid conditions extending to the western parts of the country.

Figures 3 and 4 show rainfall projections for the intermediate and more distant future for Upington, which is in the lower Orange basin. The figures show increased variability in rainfall and a decrease in rainfall becoming worse for the more distant future.

According to the MNR 2007, climate change has already impacted the water sector in Lesotho whereby perennial springs have run dry and subsistence farming is in decline due to a lack of water availability as a result of recurring droughts. Future climate scenarios project reduced surface and sub-surface run-off under climate change as a result of predicted lower precipitation, recurring droughts and increased temperatures. It is estimated that the country will enter a water stress period by 2019, which is expected to worsen by 2060. Reduced rainfall under climate change translates itself into reduced run-off in the catchments. Therefore, water-based activities in the RSA are likely to be affected. Depending on the length of the dry spells, the yields of many storage dams in the LHWP are likely to be lower, leading to reduced water exports and hence lower royalties' incomes for Lesotho (Lewis & Oosthuizen 2014).

Climate change in Namibia may be difficult to account for due to the inherent variability of the climate within the different climate zones, meaning that climate change in some regions may result in more rainfall while other regions may become more arid due to a decline in rainfall combined with increased evaporation rates (MET 2010). With that said, impacts of climate change observed in Namibia have reported an increase in daily maximum temperatures. With reference to the highly variable climate of Namibia

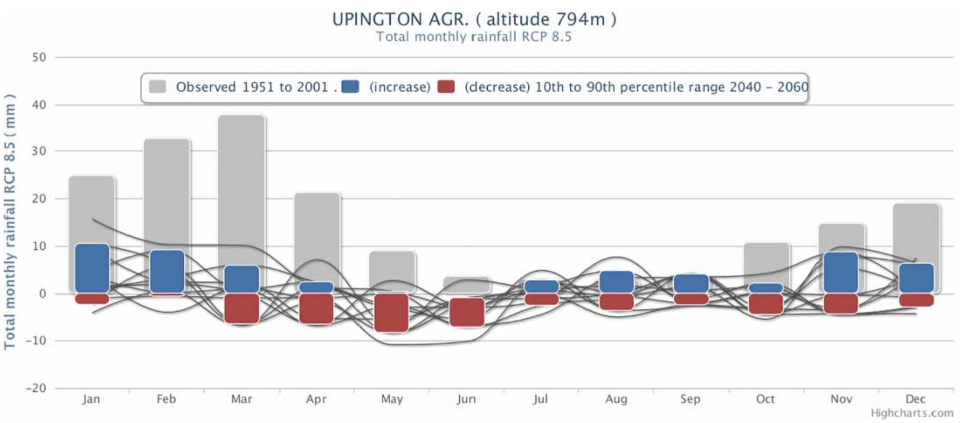

Figure 3 | Rainfall projections for Upington (lower Orange basin) for the intermediate future (2040–2060) (*Data source:* CSAG 2016).

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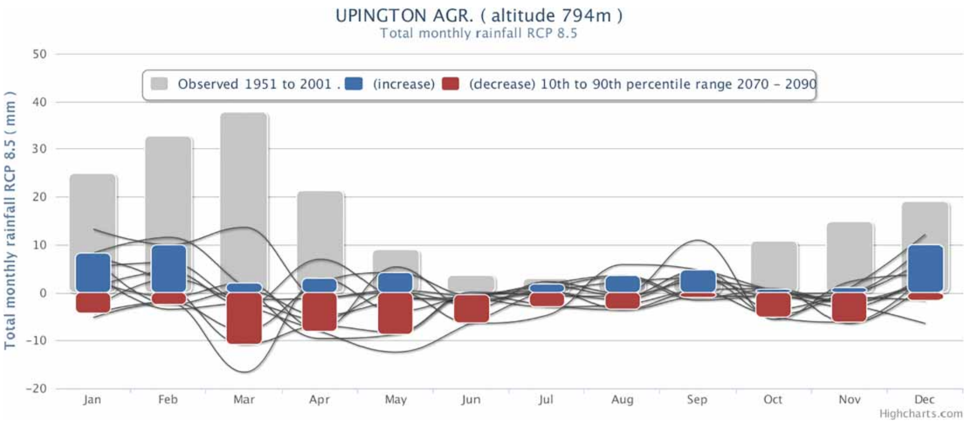

Figure 4 | Rainfall projections for Upington (lower Orange basin) for the more distant future (2070–2090) (*Data source:* CSAG 2016).

coupled with inherent uncertainty, climate change is expected to worsen and amplify its adverse impacts. Climate change predictions have indicated an increased frequency of hot days, heatwaves and droughts, and sea level rises are expected to increase by up to 30 cm. The impacts of climate change are varied and widespread across different sectors including agriculture, human health and wellbeing, energy, infrastructure, biodiversity and ecosystems. The anticipated decline in rainfall and increased temperature may cause a loss in livestock, decline in agricultural production, increased water scarcity due to low rainfall and prolonged droughts and exposure to malaria infections due to changes in rainfall patterns (Knoesen *et al.* 2009; ORASECOM 2014).

Botswana is likely to face similar impacts to those experienced in Namibia, given that two-thirds of the country is desert and water is a limited resource. Climate change is likely to be exacerbated by the inherent seasonal variation and impact on agriculture, forestry biodiversity, ecosystems and water sectors (BECCA 2008). The temperature is projected to rise between 1 and 3 degrees by 2050, resulting in higher potential evaporation rates. Future trends in rainfall are uncertain, but the overwhelming majority of general circulation models predict a rainfall decrease, possibly with more intense rainfall at a regional and local level. Overall prolonged dry spells, temporally and spatially variable rainfall are expected. Desertification is expected to worsen under the anticipated climatic changes, which will severely impact the water, agricultural/livestock and health sectors (Knoesen *et al.* 2009; ORASECOM 2014).

METHODOLOGY

Cross-cutting issues such as global climate change have introduced a combination of drivers and pressures to transboundary systems. Since its establishment, the ORASECOM has undergone many changes, including alterations in the quantity and distribution of rainfall between riparian states, economic development which required additional water to be abstracted from the shared river source, increase in water demand as a result of population growth and improvements in infrastructure, all of which reduce the flow for downstream countries. All these issues have introduced a variety of factors that need to be considered in this transboundary basin faced with changing climate and growing demands (Cooley & Gleick 2011). In the face of these changes, riparian governments, policy-makers and water managers need to be conscious of the vulnerability of transboundary watercourses. The UNEP (2009) offers a helpful DPSIR framework, which is an analytical tool used to conduct a core analysis of the vulnerability of water resources by identifying the drivers, pressures, state, impacts and responses of the resource (Figure 5). Conducting a DPSIR analysis for transboundary systems would be beneficial in order to understand the full scope of risks exposed to the shared water sources and the ways they may manifest in each riparian state.

The generic DPSIR framework in Figure 5 is as follows:

- The drivers (**D**) represent major social, demographic and economic developments in societies, which corresponds

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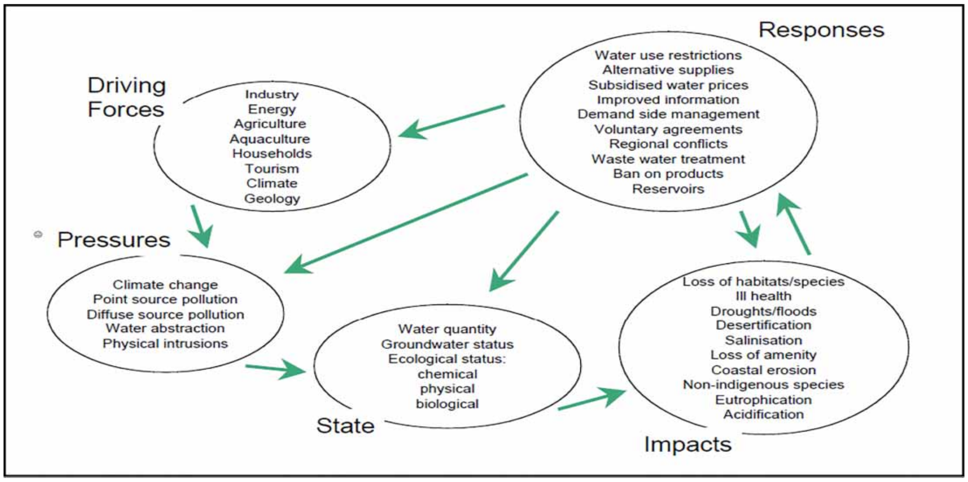

Figure 5 | A generic DPSIR framework for water (*Source:* Kristensen 2004).

with changes in lifestyles and overall consumption patterns. Demographic development may be regarded as a primary driving force, whose effects are translated through related land use changes, urbanization, industrial and agriculture development.

- Pressures (**P**) are a resultant of the driving forces and refer to processes which produce substances that affect the state of the water; that is, physical, chemical or biological substances from agricultural and industrial activities which contaminate the river, thus changing the state of the water resources on site and for downstream communities.
- The state (**S**) of water resources is described using river morphology, physical and chemical attributes which can either have positive or negative impacts.
- Impacts (**I**) can be observed that are affecting the system, as well as the determination of what is causing those impacts.
- Observation of impacts determines the necessary responses (**R**) and interventions that can be undertaken to address and improve the state of the water.

In order for this framework to be effective, the riparian states need to enter into a process of expert consultations to understand the extent of vulnerability of the water resources in each region and the ways to minimize the adverse impacts (UNEP 2009). The involvement of legal institutions and governance structures in the Orange-Senqu basin ensures collaboration and allows riparian countries to engage and address the issues that are faced by the basin; essentially, ORASECOM provides a platform for discussion on basin issues and acts as funding coordinator (Knoesen *et al.* 2009). Furthermore, in order to sustainably manage water resources it is important to assess the current state and existing impacts affecting the system in addition to how it is likely to change with time. Given the background of each basin state applying the DPSIR framework (Figure 5) to the Orange-Senqu basin will enable us to determine the vulnerability of the basin.

DISCUSSION

The DPSIR framework was used to analyse the water resources in the Orange-Senqu River basin by identifying the drivers, pressures, state, impacts and responses to climate change. This enabled the assessment to provide better understanding of the vulnerability and threats posed by climate change to this critical transboundary system. The climatic variability within the Orange River basin produces large differences in the distribution of water resources within it. Because of the difference in the natural climate of each basin state, there is a difference in rainfall distribution and the water available in each state. As a result, the main transboundary issue is water availability and allocation, as three of the four riparian states are among the driest in the SADC region. South Africa is the

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most reliant country in the basin as two of the nine water management areas are described as in water deficit and, most importantly, is the economic hub of Gauteng which uses water from the basin (DWS 2013). The driving forces in the Orange-Senqu basin are the inherent climate variability, together with the complexities introduced by climate change, and the pressures are the increased and rising water demands on the system from the industrial and agricultural sectors. The combination of decreased rainfall, increased temperatures and increased water demand will have an impact on the state water resources in the basin.

The state of water resources in the basin is described by its physical properties such as the water quality and chemical composition; however, for this study, the question of water availability in the system is of particular importance (Kristensen 2004; UNEP 2009). This is described by rainfall, runoff, surface and ground water availability and water demands. In the Orange-Senqu basin, the state of water resources is compromised by the increased water abstractions from rapid industrialization and growing population, further exacerbated by the inherent climate variability and climate change, which have begun to indicate limited water availability in the basin (ORASECOM 2014). The decline in rainfall and runoff will reduce the surface and groundwater availability, while increased water abstractions will have a negative impact on the water resource as it may lead to pollution and eutrophication, which will lead to the reduction of water quality (Knoesen *et al.* 2009).

The arid and semi-arid conditions of Namibia and Botswana also highlight the water scarcity in each country under natural conditions, and projections of future climate indicate that water scarcity is likely to persist and become worse (ORASECOM 2014). Thus, there is a need to understand how these conditions will impact the water requirements, use and allocation in the basin. In the case of Lesotho, although water stress is not the biggest concern, the change in rainfall and temperature expected when climate change considerations are introduced is of concern. It becomes clear that future projections begin to indicate the tough times that lie ahead and emphasize the need to ensure water security in the future (MNR 2007). For Lesotho, reduced rainfall may result in disputes with other basin countries over the quantity of water supplied downstream while also having to address issues of distribution and water availability for the country's population (MNR 2007). Droughts are an important issue for all basin countries. For Namibia, which has an extremely arid climate, high levels of water stress and absolute water scarcity are likely to worsen under climate change conditions, hence, water transfers from the Orange River are expected to increase in order to meet irrigation and social demand. Similar to Namibia, Botswana is likely to face the same scenario in the future. Given the low economic level and water demand that is expected to double in the next 20 years, social and environmental vulnerability are primary concerns in Botswana. Growing urbanization and industrialization in South Africa will place further demand on the basin's water resources (Kellar 2012).

Climate change impacts will intensify existing climate variability causing more floods and droughts and possible increases in arid conditions and desertification in the western parts of the basin. All these characteristics indicate that there is limited water availability in the basin and a growing water demand, and which points to water stressed conditions in the basin. The fifth and final element of the framework is the response and actions taken to address the impacts. In response to the adverse impacts, water management practices in the basin need to address water scarcity in order to ensure water availability in the future. To achieve this, joint management agreements need to be established between basin countries to monitor and ensure adequate allocation and efficient water use and legal and institutional frameworks to help guide and facilitate the water management decisions that need to be put in place to minimize conflict. Table 1 summarizes the DPSIR outcomes in the Orange-Senqu River basin.

Defining hydro-politics provided a good background and understanding from which to develop and further explain the complex dynamics within transboundary river systems. Given the nature of transboundary systems, it is expected that hydro-politics will be central to the discussion. The literature gathered has shown the importance of shared river systems across the world, in Africa and the highly impacted arid regions of Southern Africa. The most highlighted and frequently emphasized has been the socio-economic importance of shared river systems in the ability to provide water for domestic, agricultural and economic and industrial use. The steady increase in the population of countries in the SADC region coupled with increased urbanization has gradually increased water abstractions

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Table 1 | DPSIR framework for the Orange-Senqu River basin

	Lesotho	South Africa	Namibia	Botswanan
D	Climate change and climate variability	Climate change and climate variability	Climate change and climate variability	Climate change and climate variability
P	Conflicting interest	Conflicting interest	Decreased rainfall	Decreased rainfall
	Developments	Developments	Worsening arid conditions	Worsening arid conditions
	Population growth	Population growth	Developments in the upper basin, e.g., dam construction	Developments in the upper basin, e.g., dam construction
S	Deteriorating water quality and aqua-ecological status	Deteriorating water quality and aqua-ecological status	Deteriorating water quality and aqua-ecological status	Deteriorating water quality and aqua-ecological status
I	Climate extremes	Climate extremes	Decreased flow	Decreased flow
	Drought/floods	Droughts/floods	Desertification	Desertification
	Compromised supply	Change in rainfall	Eutrophication	Eutrophication
		Increasing temperature		
		Compromised supply assurance		
R	Cooperation between basin states	Cooperation between basin states	Cooperation between basin states	Cooperation between basin states
	Establishment of transboundary treaties and formal agreements	Establishment of transboundary treaties and formal agreements	Establishment of transboundary treaties and formal agreements	Establishment of transboundary treaties and formal agreements
	Strategic planning and management	Strategic planning and management	Strategic planning and management	Strategic planning and management
	Political will between riparian states is crucial	Political will between riparian states is crucial	Political will between riparian states is crucial	Political will between riparian states is crucial

and will continue to add pressure to the competing demands on the limited water resource available. This is further complicated by the inherent climate of each riparian country involved. All of these elements put transboundary systems at risk of political stress and dispute over the shared water resources, which is why it is important to establish multilateral agreements in order to strategically manage water resources between riparian countries.

In the African context on hydro-politics, the SADC Protocol for shared water resources highlights three principles, which are put in place to ensure the equitable allocation and use of water between basin states. These principles are first, to maintain a proper balance between development, environmental protection and conservation; second, co-operation in joint projects and studies; and third, information and data sharing (Turton & Henwood 2002). These principles speak to the partnership and joint management approach which is needed to minimize conflict between riparian states. The major challenge with transboundary hydro-politics is the consideration of economic development plans and infrastructure improvements in individual states. When development plans in individual states occur concurrently, intensive water use can jeopardize the environment and water resources in the basin (Turton & Henwood 2002).

The LHWP is a good example of how consideration of the economic value of water has been given in the bilateral agreement between South Africa and Lesotho. Although it may only involve two countries, this agreement is critical to the rest of the basin as the water is used for strategic and economic purposes as well as transferred and delivered to other parts of the basin. Communication is emphasized in the remaining two principles, which focus on strengthening relations between riparian states by taking on joint projects and studies which assist in the sharing of information and data, integration of information on future hydro-climatic conditions that are likely to be experienced, and understanding how these changes will impact the political landscape of how shared water resource is managed (Cooley & Gleick 2011). This allows for a conducive learning environment

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where each state can understand the impacts of climate change and how it may alter and influence the sharing of the water source. It is these principles that will ensure consideration of climate change in the Orange-Senqu basin and sustainable water use in the future (Kellar 2012). The sharing of data and information through the Orange River Replanning Study has produced a body of data that is transparent and uncontested (Turton 2005b).

The law is an integral part of transboundary treaties, thus such agreements should be legally binding to emphasize the importance of taking action against climate change impacts and sustainable growth. The benefits of a basin-wide cooperation must be shown to all stakeholders, ensuring openness and transparency so that they see that cooperative governance is better than working individually (Menga 2016). Assessment of the ORASECOM Agreement demonstrated how each country's water, climate change and future development policies and plans inform and have been integrated into the agreement and serve to ensure a basin-wide approach in the interests of all.

In the context of climate change, existing transboundary agreements will have to undergo amendments to account for changes in rainfall and temperature. This may increase tensions between riparian states as the suggested amendments may not be embraced by all adjacent states and begin to cause conflict in areas that had previously seen good cooperative governance. There is a variety of approaches that can be incorporated into existing treaties to allow for flexibility in the face of climate change, including: (1) adjustable allocation strategies and water-quality standards; (2) response strategies for extreme events; (3) amendment and review procedures; and (4) joint management institutions (Cooley & Gleick 2011). Literature shows that there are various methods where specific strategies have been successfully implemented in ways that both reduce the risks of political conflicts over shared waters and lessen vulnerabilities to climatic changes. There are key factors which create an enabling environment for the good governance of the shared water resource and development of an adequate climate change adaptation strategy (Earle 2005; Jankielsohn 2012). To begin with, the adaptation strategy needs to be established at basin level and inclusive of all parties and states, so that the benefits of the strategy are well understood and there is no negative feedback where one good strategy negatively impacts other riparian states. Political support from adjacent governments is crucial for the successful implementation of the strategy, as this will minimize any political tensions and conflict and address all concerns allowing for peaceful negotiations to establish a level of compromise (Cooley & Gleick 2011).

The impacts of climate change in the Orange-Senqu basin are inevitably causing changes in the primary climatic variables such as rainfall and temperature. Rainfall is the fundamental element in the hydrological and climatic cycle, therefore any changes to the system will have a ripple effect on water availability and water quality (Cooley & Gleick 2011). Consequently, it is important to study and understand the potential climate change impacts and the vulnerability of transboundary systems in order to take the necessary adaptive measures and interventions. Notably, the impacts of climate change were discussed using literature gathered from various authors who have brought attention to this field. Highlighting the impacts that climate change will have in each basin state has shown that transboundary management approaches used in the Orange-Senqu will have to shift from those which used to be based on the assumption that future water supply and quality will not change, because literature shows that this may not be the case. The perception of hydrological stationarity will lead to the failure of the current treaties and ORASECOM Agreements to include adequate mechanisms to account for the changing social, economic or climate conditions, which will have detrimental ramifications (Earle 2005; Cooley & Gleick 2011; Menga 2016). For this reason, there is an urgency regarding the consideration of climate change in transboundary agreements.

The framework analysed in the paper enables researchers, water science practitioners and policy-makers to analyse the Orange-Senqu basin using each of the elements. Under the key drivers, industry and agriculture should be of priority in the Orange-Senqu basin because of the continued growth experienced in the past and the trend which is foreseen going into the future. Given the high level of economic development in the basin, and its central role in a number of existing IBTs, the Orange River basin is likely to become more of a recipient basin in future if the current resource consumption trends continue. This has the capacity to increase the conflict potential within the basin,

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particularly when donor basins such as the Thukela, Incomati, Maputo and others have their own economic growth potential capped as the result of what is, in essence, a form of induced scarcity (Turton 2005a). The shortage of water in the basin may also cause a shift in the economic activity in the basin, meaning that the split between agriculture and industry may widen. This will shift what is known as sectoral water efficiency, meaning that water used for irrigation may be decreased due to the low crop yield, despite that fact that the greater proportion of the water goes to irrigation, and this will negatively impact Namibia as they depend greatly on this water. Therefore, the remaining water will be given to the industrial sector, which stands to benefit South Africa, and this is where potential conflict lies and negotiations about which state gets that water will be highly contested (Turton 2005b).

This is where flexible water allocation strategies address the challenges that come with water availability, which in many cases indicates that a decline in the amount of water will require the water allocation agreements to be reviewed in order to account for the decline in water resources, making sure that all riparian states maintain satisfactory water supply levels. Although there is vulnerability to conflict and the ORASECOM Agreement will be tested, there is hope that the institutional arrangements in place will forge transboundary cooperation that can accommodate flow variability. In many cases, a minimum flow is stipulated to be delivered by an upstream state to maintain ecological functions and human health requirements for downstream states.

CONCLUSION

Transboundary agreements in the past may have overlooked the occurrence of extreme events and their implications on water delivery; however, under climate change it is important to understand the risk posed by floods and droughts. Prolonged dry spells can lead to water-stressed conditions and failure to ensure water delivery in the basin. In such cases, it is advisable for transboundary agreements to make provisions for extreme events and establish specific guidelines that address reduced water deliveries within a basin (UNEP 2009; Cooley & Gleick 2011). An example of this practice is seen in the Colorado River basin, where seven riparian states collaboratively established specific guidelines for reduced water availability under drought and low-reservoir conditions. The water shortage guidelines, which were developed in consultation with the Mexican government, are triggered at specific reservoir water levels in major reservoirs on the Colorado River to maintain river flow (Cooley & Gleick 2011).

Coordinated flood and drought management are equally important for the good governance of water resources. Much of the literature focuses on droughts and water allocation schemes, often forgetting the threats posed by floods, especially to downstream states. For this reason, transboundary agreements need to consider the risks posed by floods in order to minimize any catastrophic disasters downstream. In the face of hydrological variation, a changing climate and other environmental factors, it is crucial for transboundary agreements to be flexible in their nature, thus allowing for review and amendments to be made. Joint management institutions create an enabling environment for good governance of shared water sources in order for the above-mentioned factors to effectively work together for the benefit of the riparian states (Cooley & Gleick 2011). Water resources research and climate science aims to provide a better understanding of natural systems and the degree and extent of change to be expected. The application of this work is crucial in the review and amendment of transboundary agreements and beneficial to policy-makers and river basin water managers to make well-informed decisions about the future of water resources under climate change conditions.

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