

Projecting River Basin Resilience in the Zambezi River Basin through Global Analyses and Basin Realities

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Abstract Projecting future hotspots of hydropolitical tension in international river basins may help countries in preventing hydropolitical conflict. The Zambezi River Basin has been identified as a basin at risk of future hydropolitical conflict. This paper analyzes the basin's hydropolitical resilience using two approaches: i) a global analysis of factors that indicate change and institutional capacity, and ii) an in-depth examination of its hydropolitical history and present-day status using interviews with basin stakeholders, academics, NGOs, and policy makers. Results of the global analysis indicate that the Zambezi River Basin has comparatively higher institutional capacity, lower to medium rates of new dam development, lower human development and security values, lower water scarcity, yet higher projected water variability. Examining the basin's hydropolitical history shows that these results are contextually dependent. This paper argues that while global hydropolitical resilience analyses are valid for indicating areas of possible tension over shared water resources, tracing basins' hydropolitical history puts the global results into context that is crucial to identify specific aspects of the basin that may push the basin into conflict.

Keywords Hydropolitics · Water conflict · Water cooperation · Hydropolitical resilience · Zambezi River Basin

1 Introduction

The world's transboundary surface water basins comprise 47 % of the earth's land area, hold 40 % of the world's population (Wolf et al. 2003a), and are relied upon for economic well-being and ecosystem goods and services. Competition for transboundary river basin resources, combined with freshwater quality and quantity declines, may lead to international conflict.

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Certain variables (or variable combinations), including rapid environmental change, increased hydrologic variability, unilaterally constructed dams, and the absence of institutional capacity (De Stefano et al. 2012; Petersen-Perlman et al. 2012), may shift a basin into conflict. The likelihood increases as the rate of change exceeds the institutional capacity to absorb it (Wolf et al. 2003a). Global variable comparisons may elicit certain basins (and countries) meriting further analyses, but may paint an incomplete picture (De Grosbois and Plummer 2015). As Principle 2 of the OECD Principles on Water Governance (2015) calls for managing water at appropriate scales and fostering coordination between different scales, the question of how scale influences effective management becomes increasingly relevant. This paper compares how the results of such a global assessment align with realities at a river basin scale. I attempt to answer the following:

1. The Zambezi River is a transboundary socio-hydrological system currently functioning across international borders in a state of relative peace. What variables (or variable combinations)—internal and external, current or legacy—could serve to push the Zambezi system into conflict?
2. What is added by analyzing hydropolitical resilience (the capacity of a system to adapt to permutations and change) at both the global and basin scale?

In this case, I will “ground-truth” the results of this global analysis of hydropolitical resilience through analyzing the Zambezi River Basin.

This article represents a new approach in analyzing the relationship between hydropolitical resilience and scale. The Zambezi River Basin’s hydropolitical resilience is worth assessing due to its many lower-income but rapidly-growing economies, its explosive projected population growth, its history of intra-basin hydropolitical tension, progress towards basin-wide cooperation, and its strong potential for physical change. The aforementioned factors have led some scholars to identify the Zambezi at risk for future conflict (Mutembwa 1998; Wolf et al. 2003b; Pearce 2013). More generally, the importance of understanding how to manage and govern the global water crisis (the World Economic Forum (2014) ranked water crises as the third-highest global risk of highest concern) is seen as crucial (UNESCO 2015).

Before analyzing the Zambezi’s hydropolitical resilience, I trace the theoretical framework of hydropolitical resilience and explore the nature of hydropolitical conflict. Next, I explain my methods for measuring hydropolitical resilience across the globe, followed by the results. I then examine the utility (and shortcomings) of the global analysis by comparing its results with the Zambezi’s realities by tracing the basin’s hydropolitical history through past events and the results of semi-structured interviews across the Basin in 2012. I conclude by arguing that while global hydropolitical resilience assessments may be useful in identifying areas of concern, a basin’s nuances must be incorporated to fully understand a basin’s hydropolitical risks and opportunities.

2 Literature Review

2.1 Hydropolitical Resilience and Hydropolitical Vulnerability

The concepts of “resilience” and “vulnerability” as related to water resources are frequently assessed within the framework of “sustainability” and relate to how biophysical systems

adapt to change (e.g., Gunderson and Pritchard 2002). As the sustainability discourse has broadened over time from describing engineered and ecological systems to include human systems, research has also been increasingly geared towards identifying indicators of resilience and vulnerability within this broader concept (e.g., Lonergan et al. 2000; Turner et al. 2003).

Many scholars have debated about conflict and its influence on transboundary water system resilience (e.g., Gleick 1993; Wolf 2000; Cooley and Gleick 2011). This debate falls within the framework of “hydropolitics” (Waterbury 1979), which relates to the ability of geopolitical institutions to manage transboundary waters in a politically sustainable manner, i.e., without tensions or conflict (McNally et al. 2009).

Examining transboundary water system resilience within hydropolitics leads to the concept of “hydropolitical resilience,” defined above. Conversely, “hydropolitical vulnerability” is the risk of political dispute over shared water systems (Wolf 2005). Basin characteristics that tend to enhance hydropolitical resilience include: international agreements and institutions, a history of collaborative projects, generally positive political relations, and higher levels of economic development. Facets that tend toward vulnerability include: rapid environmental change, increased hydrologic variability, rapid population growth, asymmetric economic growth, major unilateral development projects, absence of institutional capacity, the potential for basin “internationalization”, and generally hostile relations (Wolf 2005). When examining these characteristics combined, it appears that hydropolitical conflict is most likely with major water infrastructure built without institutions that can mitigate for their transboundary impacts (Petersen-Perlman et al. 2012).

Next, I define what constitutes hydropolitical conflict by addressing the nature of transboundary waters and conflict.

2.2 Transboundary Waters and Conflict

Scholars have debated whether the transboundary nature of water may lead to violent conflict; the debate appears to be centered on how “transboundary water conflict” is defined. Wolf (2000) argued that while there is a growing literature describing water as an historic, and, by extrapolation, a future cause of warfare, a close examination of case studies cited reveals looseness in the classification categories; in other words, how one defines water “wars.” Only 38 disputes involving water-related violence occurred between 1948 and 2008, 31 of which occurred before 1970 between Israel and one or more of its neighbors (De Stefano et al. 2010). Most disputes were: 1) caused by political tensions or instability rather than about warfare, 2) and/or using water as a tool, target, or victim of armed conflict. These are important issues, but not water “wars.” Yet there are many sub-national water related incidents of violence; generally between tribes, water use sectors, or provinces (Wolf 2000). While the likelihood of war over water is small, a long history of water-related violence exists, and future pressures, including (but not limited to) population, economic growth, and climate change, could increase tensions (Cooley and Gleick 2011).

The previous paragraph reveals discrepancies for how “transboundary water conflict” is defined. Here, I define it as verbal, economic, or militarily hostile actions between nations over shared waters, and “violent conflict” as the subset of militarily hostile actions.

Several transboundary water conflicts have occurred over unilaterally constructing large water infrastructure. Turkey’s 1990 filling of the Ataturk Dam’s reservoir interrupted the flow of the Euphrates for a month, which Syria and Iraq protested (Gleick 1993). More recently,

rhetoric escalated over worries of Ethiopia's dam construction impacting the Nile's flow; Egypt's Muhammed Morsi reportedly said, "We will defend each drop of the Nile with our blood" (Natsios 2013). This demonstrates how water management decisions can be used (or viewed) as a political weapon.

Climate change is also expected to intensify hydropolitical tensions (Gleick 1993; Yoffe et al. 2004), as it may alter river flow quantity and timing, increase water scarcity, indirectly reduce food availability, and increase exposure to new disease vectors. Consequentially, river basins without robust water-related treaties and institutions may be more vulnerable to tension and conflict (De Stefano et al. 2012). Crafting effective treaties over water should include adaptable management structures, clear and flexible allocating criteria, equitable distribution of benefits, and detailed conflict resolution mechanisms (Giordano and Wolf 2003).

Consent-building relations in water may also bring inherent weaknesses. Treaties can be exploited by not being easily enforceable, can reflect (or exacerbate) existing inequalities between riparians, and can lead to non-signatory riparians not participating; treaty presence does not indicate hydropolitical resilience alone (Zeitoun and Warner 2006). Also, party relationships, rather than institutional content or presence, may be at the heart of their success (Chasek et al. 2006). Despite these healthy critiques, the relationship of institutional capacity and decreased violent conflict holds (Wolf et al. 2003a; Yoffe et al. 2004).

2.3 Measuring Hydropolitical Resilience

Returning to Wolf et al. (2003a)'s conclusion, one needs to quantify both a) the amount of change and b) institutional capacity to determine hydropolitical resilience. Using this concept, Turton et al. (2005) based their analysis of hydropolitical resilience of African river basins and stated that a hydropolitical vulnerability analysis in Africa must examine both the underlying factors that create or drive change and the subsequent legal and social responses.

Next, I detail my approach for measuring hydropolitical resilience and vulnerability both globally and for the Zambezi River Basin, drawing from approaches used by Wolf et al. (2003b) and Turton et al. (2005).

3 Methods for Global Analysis

The paper's methodology is divided into two parts: a global and a river basin analysis. I examine hydropolitical resilience globally using social, political, and physical indicators that measure the potential for change and institutional capacity. I use two social indicators: the Human Development Index and the Human Security Index. For physical changes, I utilize data measuring water scarcity from 2003 to 2013, a dataset of projected dam construction, and a dataset of projected water variability. Finally, I examine institutional capacity through a dataset of current international water treaties from Oregon State University's Transboundary Freshwater Dispute Database. All analyses are performed at the basin-country unit (BCU) level. A BCU is defined as the portion of a riparian country's land area that is within a certain transboundary river basin.

My global hydropolitical resilience analysis serves two purposes: a) to determine the locations of higher and lower hydropolitical resilience, and b) to understand where the Zambezi River Basin fits in this context. The indicators I use fall into two broad categories: those that a) enhance and b) decrease resilience (Fig. 1).

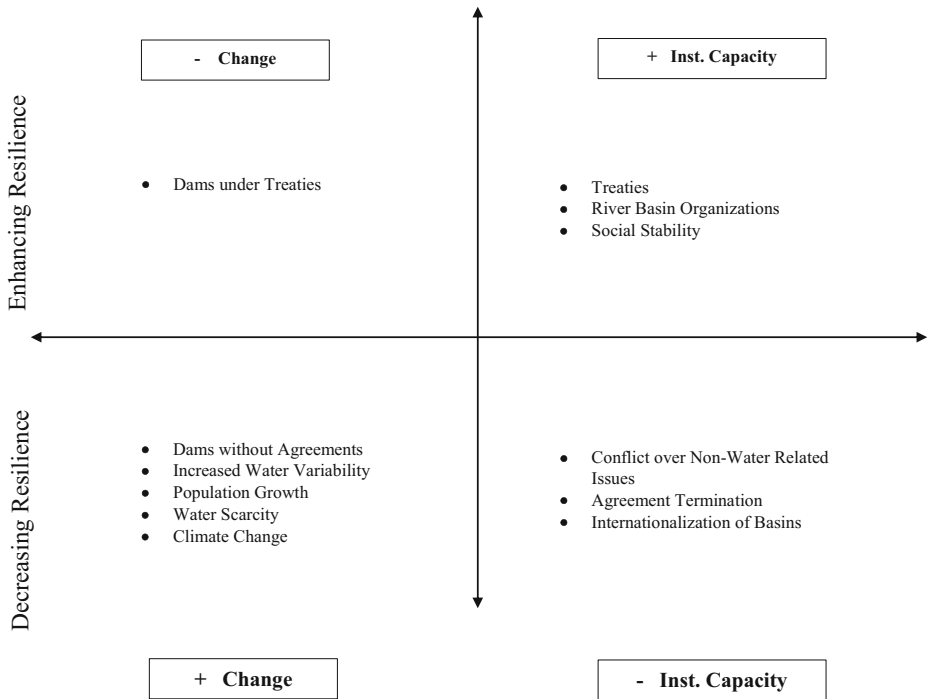


Fig. 1 Indicators that enhance and decrease hydropolitical resilience. Indicators listed in the upper left quadrant represent factors that mitigate change, enhancing resilience. Indicators listed in the upper right quadrant represent factors that enhance institutional capacity, also enhancing resilience, etc

3.1 Factors Enhancing Resilience

Two groups of factors indicate higher hydropolitical resilience: those that enhance the river basin’s institutional capacity, and those that mitigate change. This analysis uses two indices to measure each country’s social stability: the Human Development Index (HDI); a composite index created by the United Nations Development Programme that measures “average achievement in...a long and healthy life, knowledge and a decent standard of living” (UNDP 2012, p.1) and the Human Security Index (HSI), which combines over 30 economic, environmental, and social components to measure the human condition worldwide (Human Security Index 2012).

The presence and content of treaties and river basin organizations (RBOs) ostensibly enhance hydropolitical resilience. Each BCU is scored by the presence or absence of the following three aspects, adapted from De Stefano et al. (2012): at least one treaty with an allocation mechanism; at least one treaty with a mechanism for hydropower, flood control, or dam construction; and at least one treaty with a conflict resolution mechanism.

3.2 Factors Mitigating Change/Exacerbating Change

Dams may mitigate change by storing water in droughts or by moderating the pace of floodwater moving downstream. Dams may also alter the hydrograph, inhibit aquatic species

migration, and alter nutrient-carrying sediment distribution. Dams constructed in upstream riparians without an agreement in place is one of the strongest indicators of a basin's hydropolitical tensions (Wolf et al. 2003b). To that end, I examine the potential for dam construction both globally and within the Zambezi River Basin.

I gathered information regarding dams exceeding 10 MW in capacity and diversion projects that are planned, proposed, and under construction from the International Rivers Network, the International Commission on Large Dams (ICOLD), the United Nations Framework Convention on Climate Change's Clean Development Mechanisms, and from other organizations' websites known to fund dam construction (e.g., World Bank). I used coordinates of each project's location when possible; when unavailable, I identified each dam's BCU by its river or state/province/region. Dams or diversion projects whose BCU could not be determined by either method were excluded. Dam density was calculated for each BCU. Each BCU was assigned a score based on its total dam density (one point for high density, two for medium, three for low) and its institutional capacity (one point for each mechanism present). The BCUs with the lowest scores are at highest risk for conflict, and vice versa.

3.3 Factors Decreasing Resilience

While seasonal water resource deficits can lead to short-term conflicts, long-term drought and anthropogenic-caused water scarcity may exacerbate international tensions. The GRACE satellite (NASA and the European Space Agency) measures monthly changes in water storage anomalies. Using GRACE data the Sen's-slope (Sen 1968) measures the overall trend without being over-influenced by abnormally wet or dry periods. I utilize Sen's slope calculations made in De Stefano et al. (2015), which calculated the spatial mean of the Sen's slope for each BCU at 1° resolution over a period of 127 months ending in July 2013.

Predicting future water variability can also project high rates of change. De Stefano et al. (2012) calculated river basin resilience to future climate change-induced water variability by classifying baseline and future changes in hydrological variability and by classifying their institutional capacity for hydrologic variability for each BCU.

I next discuss the results of my global analysis of hydropolitical resilience for the BCUs of the Zambezi River Basin.

4 Results and Discussion of Global Analysis

4.1 Factors Enhancing Resilience

Overall, the Zambezi River Basin countries have low HDI and HSI scores (Table 1), including the four countries that have the highest populations in the Zambezi (Malawi, Mozambique, Zambia, and Zimbabwe). Only Botswana and Namibia have values in the middle 50 % of all BCUs for both social stability indicators.

The Zambezi's treaty coverage for all BCUs (except DRC) is comparatively high (Fig. 2). The presence of bilateral and trilateral agreements, the Zambezi River Commission (ZAMCOM) and its allocation mechanisms for allocation, conflict resolution, and variability management, allows for a higher score.

Table 1 Values for each BCU in the Zambezi River Basin. HDI and HSI are Human Development Index and Human Security Index, respectively

Country	HDI	HSI	Sen's Slope	2030 Variability	2050 Variability
Angola	0.508	0.460	0.1729	0.546	0.428
Botswana	0.634	0.634	0.2513	1.427	1.342
DRC	0.304	0.350	N/A	0.461	0.349
Mozambique	0.327	0.482	0.1143	0.403	0.447
Malawi	0.418	0.462	0.0162	0.349	0.346
Namibia	0.608	0.609	0.2522	1.126	1.102
Tanzania	0.476	0.509	-0.0270	0.351	0.344
Zambia	0.448	0.438	0.1701	0.444	0.383
Zimbabwe	0.397	0.380	0.0957	0.540	0.655
Average of all BCUs (Countries for HDI and HSI)	0.658	0.597	-0.0007	0.417	0.403

Each HDI and HSI value represents the country's value, not the specific value of the BCU

4.2 Factors Decreasing Resilience

Riparians in the Zambezi have seen an overall modest increase in water storage basin-wide according to the GRACE data. Only Tanzania's BCU had a water storage decrease. Results suggest that the Zambezi is comparatively resilient over the 127 month period compared with the Tigris-Euphrates and Ganges-Brahmaputra-Meghna, which had large decreases (Table 1).

The Zambezi's BCUs have low (Malawi, Mozambique, Zambia) to medium (Tanzania, Zimbabwe) projected dam densities (Fig. 3). Angola, Botswana, DRC, and Namibia have no projected dams, which aligns with their comparatively small shares of the basin area and population.

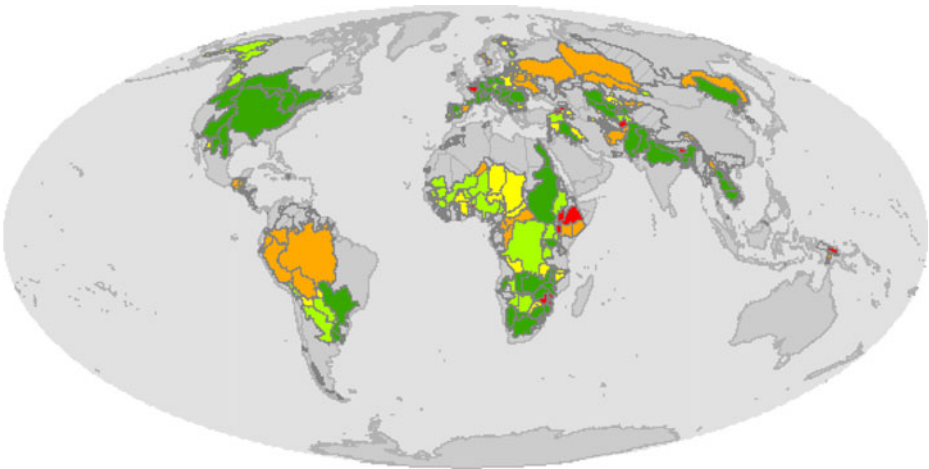


Fig. 2 Treaty coverage for global BCUs. Dark green represents treaty coverage with all five treaty attributes present (presence of a treaty, presence of a RBO, presence of conflict resolution mechanism, presence of a variability management mechanism, and presence of an allocation mechanism). Light green represents treaty coverage with four treaty attributes present, yellow three attributes, orange two attributes, and red one attribute. The slant pattern represents BCUs without treaties

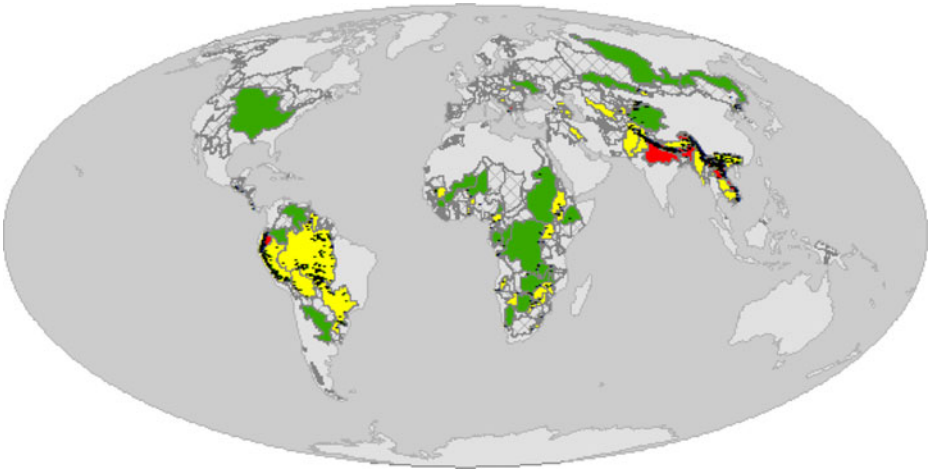


Fig. 3 Projected dam densities for global BCUs. Red represents high dam densities, yellow represents medium, and green represents low. The crosshatch pattern represents BCUs without new dams

The World Bank study projects the Zambezi's runoff variability to be highest overall in Botswana, Namibia, and Zimbabwe, respectively in both 2030 and 2050 (Table 1). In 2030, high variability is projected in the majority of the basin, especially in upstream BCUs. In 2050, the Zambezi's projected runoff variability is high in Botswana, Namibia, and Zimbabwe, while medium in Malawi and Mozambique.

4.3 Discussion of Global Analysis Results

The water scarcity trend (Sen's slope), treaty coverage, and projected dam development all indicate comparatively higher projected hydropolitical resilience. Meanwhile, the social stability factors used for this analysis have low values, indicating decreased hydropolitical resilience. The higher projected climatic variability in 2030 and 2050 also indicates decreased hydropolitical resilience.

These "mixed" results do not necessarily nullify each other, with comparatively high treaty coverage and low social stability values not indicating that the Zambezi Basin has a "medium" risk of hydropolitical tension. Rather, these indicators try to show where hydropolitical tensions are more likely to occur.

Next, I explore the validity of the global analysis' conclusions by examining the history of the states that have signed these treaties and the evolution of the relationships between them.

5 Hydropolitical Resilience Analysis of the Zambezi River Basin

While these results may serve as a guide, they mask the nuances on the ground. To uncover these nuances, this section examines the political history of cooperation and conflict, as well as past, current, and predicted physical, political, and social changes to the basin. I also incorporate information gathered from 25 semi-structured interviews and surveys in Botswana, Mozambique, and Zambia with academics, NGOs, policy makers, governmental officials, and citizens displaced by dam construction that helped to inform its current hydropolitics.

5.1 Study Area

The Zambezi River Basin is the fourth-largest waterway in Africa and the largest African river system that flows into the Indian Ocean (Isaacman and Isaacman 2013). Angola, Botswana, D.R.C.,¹ Malawi, Namibia and Tanzania can be considered upstream countries, while Zambia, Zimbabwe, and Mozambique can be considered downstream countries. Zambia and Zimbabwe each have a large percentage of the basin's area.

Arguably the most pivotal event that shaped (and continuously shapes) the Zambezi River Basin's hydropolitics occurred when European colonial powers divided the Zambezi Basin in the 1884–1885 Berlin Congress, creating, more or less, the basin's modern-day borders. The British, Germans, and Portuguese instituted arbitrary political boundaries, completely ignoring existing political, cultural, ethnic, and linguistic regions. Most riparians obtained political independence during the 1960s and 70s.

5.2 Before the Dams

The Zambezi River Basin has one of the most highly variable climates of any major river basin in the world, with the north being much wetter than the water-stressed south (Beilfuss 2012), and extreme flow variability (Isaacman and Isaacman 2013). The basin also has experienced catastrophic flooding, typically inundating the banks of the Zambezi during the December–March rainy season. The receding waters left nutrient-rich deposits, very desirable for agriculture, along the river's shoreline, sometimes over several kilometers (Isaacman and Sneddon 2000).

5.3 Dam Construction

At least 30 dams with a storage capacity in excess of 12 MCM have been built for domestic, industrial, mining, irrigation, and power generating purposes (World Bank 2010). Almost 5000 MW of hydropower has been developed, with a total potential development of 13,000 MW (World Bank 2010). Malawi (4), Mozambique (1), Zambia (6) and Zimbabwe (21) have large dams; the Kariba Dam spans the Zambezi mainstem between Zambia and Zimbabwe.

Arguably, large dam construction has been the most influential physical change for the basin and its hydropolitics. Kariba was the first major dam built and has the largest reservoir by volume in the world (Beilfuss 2012). Since its construction, Kariba has been the main source of energy for the Zambian-Zimbabwean interconnected electricity supply system. The next major dam, Mozambique's Cahora Bassa, was finished 6 months after Mozambique's 1974 independence, becoming the world's fifth largest hydroelectric power installation (Isaacman and Sneddon 2000).

The construction of Kariba, Cahora Bassa, and other dams has had several biophysical and socio-economic impacts. Today's displaced Gwembe Tonga populations and their descendants are still impacted. When interviewed, surviving members of former Gwembe Tonga communities in Zambia discussed how their community was split between Zambia and Zimbabwe when Lake Kariba came into being. Farming was disrupted; many Gwembe Tonga would rely on two growing seasons for food: the dry season with riverbank flood-recession agriculture, and the rainy season with rain-fed agriculture in the nearby highlands. Gwembe Tonga reportedly

¹ D.R.C. has a very small area within the Zambezi River Basin and does not participate in ZAMCOM or in any other Zambezi RBO.

starved, suffered from diseases, and had slim economic opportunities after their forced departure from the riverbanks. The Zambezi delta, described as the “lifeline of central Mozambique” and “one of the most productive and biologically diverse tropical floodplains in Africa” has also been adversely affected with wetland and tropical area reductions, non-local vegetation infestations in stagnant waterways, and saltwater intrusions (International Crane Foundation *N.d.*).

Nearly all elder Gwembe Tonga interviewees mentioned the abundance of fish and the bounty of vegetables grown using floodplain-recession agriculture before the dams; this was also cited by other elders in Mozambique’s Tete region who were similarly displaced by the Cahora Bassa Dam (Isaacman and Sneddon 2000). Today, the fishing industry is limited at the reservoirs, but overfished, according to villagers living nearby. Isaacman and Sneddon (2000) noted, however, that in light of the enormous poverty which peasants in this region are experiencing today, there is a tendency to romanticize the period before the dams, and accounts of previous relative food security and prosperity should not be accepted uncritically.

5.4 Hydropolitical Conflict and Cooperation in the Zambezi

Though very few water conflicts in the Zambezi have occurred solely between riparian states, many subnational conflicts have occurred; most frequently between state agencies and local communities over water resources projects (Fox and Sneddon 2007).

Hydropolitical cooperation within the Zambezi started in the early 1950s when the British colonial governments of Northern (present-day Zambia) and Southern Rhodesia (Zimbabwe) built the Kariba Dam to provide energy to Northern Rhodesia’s copper mines and Southern Rhodesia’s agricultural and mining sectors (Klaphake and Scheumann 2009). Northern and Southern Rhodesia established the Central African Power Corporation (CAPCO) to finalize construction work and operate the dam, which was abolished and replaced by the Zambezi River Authority (ZRA) in 1987 (Klaphake and Scheumann 2009).

Independence movements in the 1960s changed the Zambezi’s hydropolitical and geopolitical dynamics. The white minority-ruled Rhodesia Front’s unilateral declaration of Rhodesia’s independence aided in developing a conflict regarding CAPCO’s assets. The United Nations imposed mandatory economic sanctions against Rhodesia, which Zambia strictly observed – leading to what Mutembwa (1998, *n.p.*) classified as a “situation of non-recognition and acute hostility as the overall framework” between the two countries until Zimbabwe’s 1980 independence. Relations were so strained that the Zambian government was forced to request British troops to guard Kariba following reports that saboteurs on the Rhodesian government’s payroll were charged with destroying it (Chenje 2003).

The Cahora Bassa Dam has also seen political controversy. Portuguese colonial officials hoped Cahora Bassa would lead to expanded irrigation, mining, and flood protection, thereby stimulating European settlement, communication, and transportation throughout the Zambezi valley. They also argued that the dam would provide power to South Africa, giving colonials much needed revenue to spur further development (Isaacman and Sneddon 2000). FRELIMO (The Front for the Liberation of Mozambique) launched a series of attacks near the dam site to subvert the scheme, claiming Cahora Bassa as a symbol and instrument of colonial oppression (*Ibid.*). After independence, the newly installed FRELIMO government radically shifted, rebranding Cahora Bassa as a symbol of liberation that would lead to greater economic prosperity, but in the 20 years following independence, Rhodesian and then South African-backed RENAMO guerrillas sabotaged Cahora Bassa’s power lines to paralyze the dam and destabilize Mozambique’s newly installed government (Isaacman and Sneddon 2000).

Early attempts at basin-wide cooperative management were only somewhat successful. This included 1987's ZACPLAN, which was adopted by five riparian states² (Nakayama 2003), and consisted of 19 projects (called "Zambezi Action Projects"); only one was implemented, which developed an integrated water management plan for the basin (ZACPRO 6). Next was 2000's Southern African Development Community (SADC) Revised Protocol on Shared Water Course Systems and ratified by all 14 SADC states (including states outside of the Zambezi River Basin) (World Bank 2010). Neither ZACPLAN nor the SADC Protocol had a provision for resolving conflicts between riparian states. The SADC Protocol also did not recognize adverse social and ecological effects of river basin development, or make basin states surrender any autonomy, leading to environmental securitization at the expense of socio-ecological security (Fox and Sneddon 2007); however Article 4 contains provisions that stipulate an obligation to consult with or notify its riparian neighbors before implementing measures with "possible adverse effects" (SADC 2000).

The latest iteration of basin-wide cooperation is ZAMCOM, which has been signed by seven of eight riparian countries (World Bank 2010). Zambia has not signed, yet announced its intention to sign in 2013 (ZAMCOM 2013); apparently awaiting the conclusion of the policy reform process and institutional alignments (World Bank 2010). In July 2009, in the absence of a ratified agreement, Zambezi Basin ministers responsible for water adopted an interim ZAMCOM governance structure, and agreed upon the establishment of an interim secretariat (World Bank 2010). The organization officially came into force in 2011 (ZAMCOM 2013).

5.5 Current Status in the Zambezi

More recently, Mozambique, Zambia, and Zimbabwe have made incremental progress in data sharing and exchanging information regarding hydrologic data. Though cooperation may not be strictly codified, according to a Mozambican official, Zambia and Zimbabwe notifies Mozambique about releases of water from their reservoirs. Government officials interviewed in both Mozambique and Zambia were both in favor of further exchanges of hydrologic information.

Even with ZAMCOM in effect, there still are significant potential barriers for effective basin-wide cooperation, including climate change, pollution, rapid population growth, poverty, weak institutional and legal frameworks, a fragmented water management approach, and a lack of comprehensive knowledge of the water resources available (Chenje 2003).

5.6 Projected Climate Variability

While Angola and Zambia are predicted to have more adequate future water supplies, the rest of the basin is either currently or are predicted to face shortages. Namibia has no perennial inland rivers and has great difficulty in meeting current demand; Botswana relies on groundwater (which is insufficient to meet growing demand), and while Mozambique, Tanzania and Zimbabwe currently have "reasonable" water resources, they are predicted to suffer water stress by 2025 (Chenje 2003). Other key risks to the Zambezi River Basin predicted over the next century include significant warming, increased open-water evaporation, decreased rainfall, increasing water stress, and changing seasonal rainfall patterns (Beilfuss 2012).

² Botswana, Mozambique, Tanzania, Zambia and Zimbabwe.

5.7 Future Infrastructure Possibilities/Hydropolitical Vulnerabilities

Perhaps the most pressing matter at hand in the Zambezi Basin is the potential collapse of Kariba Dam, where the dam wall has reportedly developed “serious structural weaknesses” and was on the verge of collapse, potentially endangering at least 3.5 million people downstream (Warhose 2014).

Landlocked Malawi and Zambia are very interested in using the Zambezi as a cheap shipping route. Malawi, Zambia, and Mozambique reportedly signed a trilateral memorandum of understanding on shipping in April 2007 (Inter Press Service 2007) and have received a grant from the African Development Bank to conduct a feasibility study for this project (SADC 2012). This has been postponed, as Mozambican authorities reportedly refused to allow barges up to Nsanje, Malawi (Nyasa Times 2012).

Population growth will certainly place more demands on the Zambezi’s resources; Africa has grown at 2.55 % annually in 2010–2015. Basin countries Angola, D.R.C. Malawi, Tanzania and Zambia are projected to increase their populations at least fivefold by 2100 (UN 2015).

Though there are now few viable, undeveloped potential dam sites within the basin left (Chenje 2003), a few are worth mentioning as they might alter the basin’s hydropolitical resilience. Mozambique’s construction of the Mphanda Nkuwa Dam, while providing additional hydroelectric power, will create more challenges in ameliorating negative hydrological and ecological impacts of the large dams upstream (Fox and Sneddon 2007). Zambia and Zimbabwe’s Batoka Gorge hydropower scheme has also been identified as a potential “hydropolitical hotspot” (Boege 2009). These dams could also affect existing dam operations, particularly Cahora Bassa (Cohen Liechti et al. 2015).

The Zambezi is undergoing a “dramatic swing” from developing non-consumptive uses (mainly hydropower) to consumptive uses (Mutembwa 1998). This includes water transfers, including the proposed project supplying 495 MCM per year of water to Botswana and South Africa from the Zambezi (Creamer Media Reporter 2014); South Africa’s Zambezi Africa plan to divert water from the Zambezi through Botswana to Pretoria (Swain 2012); the planned Zambezi diversion to Bulawayo, Zimbabwe; and irrigation expanding basin-wide. The Gwayi-Shangani dam is the first step of this planned Bulawayo diversion (Fox and Sneddon 2007) in the Matabeleland Zambezi Water Project. This project is also notable due to Zambia’s previous opposition of this project and ZAMCOM’s subsequent approval (Tshuma 2011).

5.8 Summary

The scores from the indices paint a partial picture of the Zambezi Basin, but without the nuance that the history brings, it is hard to interpret these scores and whether they paint a *correct* picture. Next, I discuss whether each indicator score accurately reflects the Zambezi’s hydropolitical resilience.

6 Discussion

To summarize, the indicators suggest low social but mixed physical, and high institutional hydropolitical resilience for Zambezi basin countries. I now discuss how these results match the realities on the ground.

6.1 Factors that may Enhance Resilience

The low social indicator scores imply that most Zambezi countries are less “developed” and “secure”. These results correspond to low Political Stability and Absence of Violence/Terrorism and Government Effectiveness indicator scores from the World Bank’s (2015) Worldwide Governance Indicators. One significant flaw of using these indices to measure hydropolitical resilience is the lack of scale, as these low scores may not accurately reflect the status within the entire BCU.

The Zambezi River Basin has a high institutional capacity score due to ZAMCOM and its mechanisms for allocation, conflict resolution, and variability management. Yet the mere *presence* of these mechanisms does not equate *effectiveness*. Klaphake and Scheumann (2009, p. 67) argued that the Zambezi basin is an example of “successful harmonious or symmetrical cooperation issues, which transformed into strong organizational forms of regional cooperation.” This statement appears to be based largely on ZRA operations as opposed to a basin-wide perspective. But, one bilateral cooperative entity and a newer, untested RBO does not necessarily create strong regional cooperation. Swain (2012) described how major basin countries that are part of ZAMCOM have very little interest in joint river management, being chiefly motivated by expected international support for their planned unilateral water projects.

Part of my questioning of ZAMCOM’s effectiveness connects with Zambia’s lack of formal participation. Zambia wants comparatively greater power within the ZAMCOM framework due to its majority share of the Zambezi’s land area and highest share of water resources. Zambia has also expressed reluctance at the prospect of entering the basin framework due to perceptions that it would compromise their development plans. Yet, ZAMCOM has been designed with hopes that Zambia will join; the first Interim Secretariat was *Zambian*. Pearce (2013) compared Zambia’s lack of joining ZAMCOM to China’s absence in the Mekong Basin Commission, as both RBOs are disadvantaged by missing the biggest and most upstream countries in each respective basin. Zambia has also not supported Zimbabwe’s water transfer project to Bulawayo, which was reportedly approved by ZAMCOM. Zambia loses some ability to influence the hydropolitical agenda of the Zambezi at large by not being a full member.

6.2 Factors that may Decrease Resilience

Results from the Sen’s slope calculations for water scarcity indicate that on average, the basin has not suffered from water scarcity within recent years. With a 1° resolution, the GRACE data may not show more localized drought areas, such as the droughts in Bulawayo, Zimbabwe, during the last decade. This is especially notable as the planned, controversial Matabeleland Zambezi Water Project is meant to directly remedy Bulawayo’s chronic water shortages. The scarcity measurement also does not incorporate water pollution; nutrient emissions in Africa are projected to double or triple over the next 40 years, leading to increased eutrophication, biodiversity loss, and threaten drinking water, fishery, aquaculture and tourism ecosystem services (Ligtvoet et al. 2014).

Potential dam development is indicated to be comparatively low to average within Zambezi BCUs. Yet not all dams have equal impacts. The Batoka Gorge Dam is planned to be cooperatively built with Zambia and Zimbabwe, presumably lessening basin-wide controversy. In contrast, Zimbabwe’s construction of the Gwayi-Shangani Dam will inevitably be more

controversial. Also, calculating dam densities does not capture the significant changes that may be felt by displaced populations and ecosystems downstream, nor presents a full inventory of any dam's impacts; larger, upstream dams have greater impacts.

Though it is impossible to verify the results of the World Bank study at present, basin residents are already noticing the effects of climate change; many interviewees mentioned the change of the timing and intensity of the rainy seasons.

7 Conclusion

This paper has performed a global analysis of hydro-political resilience in transboundary river basins, as well as that of the Zambezi River Basin. Findings show that while the Zambezi Basin may be perceived as having higher political (and physical, according to some indices) resilience through a global analysis, evidence at the basin scale may be contradictory. The discussed indicators are instructive for a larger story of comparative resilience between BCUs. But these comparisons have limitations. Scoring by BCU treats each BCU as a "closed system." The reality, of course, is that these physical and political boundaries are permeable; outside events may heavily influence internal hydro-politics.

Policy makers should be attuned to the huge amount of poverty nearest the Zambezi, especially among displaced peoples and their descendants.

The ecological consequences of the dams greatly affect the entire river basin's resilience. New dams could also affect the Zambezi's tourism industry, with Batoka Gorge, as well as Victoria Falls, the Mana pools and Lake Kariba being popular destinations.

Functional basin-wide cooperation is and will continue to proceed incrementally. Considering that the weakly enforced ZACPLAN was considered to be the "guiding document" of basin management 16 years after its initiation, and that negotiations on ZAMCOM'S establishment took over a decade to conclude, suggests that functional and successful basin-wide management will progress slowly. The growth rate of the Zambezi Basin's institutional capacity may not match the rate of change that the basin might face.

This analysis has its limitations. With over 40 million people, eight countries, and thousands of plant and animal species, it is impossible to incorporate everything that may influence a system's hydro-political resilience. But, again, while global indicators may point towards basins and BCUs of low hydro-political resilience, hydro-political resilience may not truly be understood without delving into its history.

In conclusion, this paper contributes to the conversation of how to project hydro-political resilience and the approaches with which to do it. While I am not suggesting that chronicling a basin's hydro-political history and interviewing small numbers of basin stakeholders, policymakers, and government officials is the best approach to measure hydro-political resilience, I posit that more nuanced approaches to measuring hydro-political resilience are needed at the basin (and basin-country) scale.

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Compliance with Ethical Standards

Conflict of Interest The author declares that he has no conflict of interest.

Research involving Human Participants and/or Animals All interviewees were not identified in the article. The author underwent an approval process under its institution's Internal Review Board and was approved.

Informed Consent All interviewees were given informed consent.

References

- Beilfuss R (2012) A risky climate for southern African hydro: assessing hydrological risks and consequences for Zambezi River Basin dams. *International Rivers*, Berkeley, USA
- Boege V (2009) Transboundary water governance in regions of weak statehood. In: Swatuk LA, Wirkus L (eds) *Transboundary water governance in southern Africa: examining underexplored dimensions*. Nomos Verlagsgesellschaft, Baden-Baden, Germany
- Chasek PS, Downie DL, Brown JW (2006) *Global environmental politics*, 4th edn. Westview Press, Boulder
- Chenje M (2003) State of the environment in the Zambezi Basin 2000. Maseru, Lusaka and Harare: SADC, IUCN, ZRA, and SARDC, 2000
- Cohen Liechti T, Matos JP, Boillat J-L, Schleiss AJ (2015) Influence of hydropower development on flow regime in the Zambezi River Basin for different scenarios of environmental flows. *Water Resour Manag* 29(3):731–747
- Cooley H, Gleick PH (2011) Climate-proofing transboundary water agreements. *Hydrol Sci J* 56(4):711–718
- Creamer Media Reporter (2014) ILISO Consulting takes on the engineering challenge of massive water transfer scheme in Botswana. Creamer Media's Engineering News. 24 February: <http://www.engineeringnews.co.za/article/iliso-consulting-takes-on-the-engineering-challenge-of-massive-water-transfer-scheme-in-botswana-2014-02-24>. Accessed 18 April 2014
- De Grosbois D, Plummer R (2015) Problematizing water vulnerability indices at a local level: a critical review and proposed solution. *Water Resour Manag* 29(14):5015–5035
- De Stefano L, Edwards P, De Silva L, Wolf AT (2010) Tracking cooperation and conflict in international basins: historic and recent trends. *Water Policy* 12(6):871–884
- De Stefano L, Duncan J, Dinar S, Stahl K, Strzepek K, Wolf AT (2012) Climate change and the institutional resilience of international river basins. *J Peace Res* 49(1):193–209
- De Stefano L, Petersen-Perlman JD, Sproles E, Eynard J, Wolf AT (2015) Chapter 3: transboundary river basin indicators assessment. In: *Transboundary river basins: a global comparative assessment of baseline status and future trends*. Volume III: River basins. Transboundary Waters Assessment Program. Unpublished report
- Fox CA, Sneddon C (2007) Transboundary river basin agreements in the Mekong and Zambezi basins: enhancing environmental security or securitizing the environment? *Int Environ Agreements-P* 7(3):237–261
- Giordano MA, Wolf AT (2003) Transboundary freshwater treaties. In: Nayakama M (ed) *International waters in southern Africa*. United Nations University Press, Tokyo, pp 71–100
- Gleick PH (ed) (1993) *Water in crisis: a guide to the world's fresh water resources*. Oxford University Press, New York
- Gunderson LH, Pritchard L (eds) (2002) *Resilience and the behavior of large-scale systems*. Island Press, Washington DC
- Human Security Index. (2012) Human security index: about. http://www.humansecurityindex.org/?page_id=2. Accessed 19 April 2014
- Inter Press Service (2007) New Zambezi waterway planned. Southern Africa Documentation and Cooperation Centre. May 15. <http://www.sadoc.at/news/2007/2007-050.shtml>. Accessed 10 April 2014
- International Crane Foundation (N.d.) Large dams and the degradation of the Lower Zambezi Valley. <http://www.savingcranes.org/large-dams-and-the-degradation-of-the-lower-zambezi-valley.html>. Accessed 26 April 2014
- Isaacman AF, Isaacman BS (2013) *Dams, displacement and the delusion of development: Cahora Bassa and its legacies in Mozambique, 1965–2007*. Ohio University Press, Athens, OH
- Isaacman AF, Sneddon C (2000) Toward a social and environmental history of the building of Cahora Bassa Dam. *J S Afr Stud* 26(4):597–632
- Klaphake A, Scheumann W (2009) Understanding transboundary water cooperation: Evidence from sub-Saharan Africa. In: Swatuk LA, Wirkus L (eds) *Transboundary water governance in southern Africa: examining underexplored dimensions* Nomos Verlagsgesellschaft, Baden-Baden, Germany
- Ligtvoet W, Hilderink H, Bouwman A, Puijtenbroek P, Lucas P, Witmer M (2014) *Towards a world of cities in 2050. An outlook on water-related challenges*. Background report to the UN-Habitat Global Report. Netherlands Environmental Assessment Agency, Bilthoven

- Loneragan S, Gustavson K, Carter B (2000) The index of human insecurity. AVISO Bulletin, Ottawa, ON: GECHS, 6: 1–11
- McNally A, Magee D, Wolf AT (2009) Hydropower and sustainability: Resilience and vulnerability in China's powersheds. *J Environ Manag* 90:S286–S293
- Mutembwa A (1998) Water and the potential for resource conflicts in southern Africa. Occasional Paper No. 3. Global Security Fellows Initiative. University of Cambridge. [https://www.dartmouth.edu/~gsfi/gsfweb/htmls/papers/text3.htm#Chapter 5](https://www.dartmouth.edu/~gsfi/gsfweb/htmls/papers/text3.htm#Chapter%205). Accessed 31 March 2014
- Nakayama M (2003) International waters in southern Africa. United Nations University Press, Tokyo
- Natsios A (2013) Egypt's three challenges. *US News & World Report*, August 2. <http://www.usnews.com/opinion/blogs/world-report/2013/08/02/egypts-three-challenges-its-coup-its-economy-and-the-nile-river>. Accessed 19 August 2013
- Nyasa Times (2012) Malawi retreats on Shire-Zambezi navigation. *Nyasa Times*. 11 February. <http://www.nyasatimes.com/2012/02/11/malawi-retreats-on-shire-zambezi-navigation/>. Accessed 18 April 2014
- OECD (2015) OECD Principles on Water Governance, OECD Publishing, <http://www.oecd.org/gov/regional-policy/OECD-Principles-on-Water-Governance-brochure.pdf>
- Pearce F (2013) Zambezi: The Mekong's diplomatic debacle on repeat. *Agriculture and Ecosystems Blog*. 12 September. <http://wle.cgiar.org/blogs/2013/09/12/zambezi-the-mekongs-diplomatic-debacle-repeats/>. Accessed 18 April 2014
- Petersen-Perlman JD, Veilleux JC, Zentner M, Wolf AT (2012) Case studies on water security: analysis of system complexity and the role of institutions. *J Contemp Water Res Educ* 149(1):4–12
- SADC (2012) Multinational Malawi/Mozambique/Zambia: Feasibility study for the navigability of Shire-Zambezi waterways. General Procurement Notice. <http://www.afdb.org/fileadmin/uploads/afdb/Documents/Project-related/Procurement/GPNSADCWaterways%20%204-12.pdf>. Accessed 18 April 2014
- SADC (Southern African Development Community) (2000) Revised protocol on shared watercourse systems in the Southern African Development Community region. Southern African Development Community, Gaborone
- Sen PK (1968) Estimates of the regression coefficient based on Kendall's Tau. *J Am Stat Assoc* 63:1379–1389
- Swain A (2012) Understanding emerging security challenges: threats and opportunities. Routledge, New York
- Tshuma N (2011) SADC countries agree on Zambezi water. *Newsday*. 30 September. <http://www.newsday.co.zw/article/2011-09-30-sadc-countries-agree-on-zambezi-water>. Accessed 18 April 2014
- Turner BL II, Kasperson RE, Matson PA, McCarthy JJ, Corell RW, Christensen L, Eckley N, Kasperson JX, Luers A, Martello ML, Polsky C, Pulsipher A, Schiller A (2003) A framework for vulnerability analysis in sustainability science. *Proc Natl Acad Sci U S A* 100(14):8074–8079
- Turton A, Earle A, Malzbender D, Ashton PJ (2005) Hydropolitical vulnerability and resilience along Africa's international waters (Chapter 2). In: Wolf AT, Macomber MF (eds) *Hydropolitical vulnerability and resilience along international waters: Africa*. United Nations Environment Programme, Nairobi, Kenya
- UN (2015) *World Urbanization Prospects: The 2015 Revision*. United Nations, New York
- UNESCO (2015) *The United Nations world water development report. Water for a sustainable world*. United Nations Educational, Scientific and Cultural Organization, Paris
- United Nations Development Programme (UNDP) (2012) Table 1 dataset notes. <https://data.undp.org/api/assets/ID12A5BB-5609-41EE-AEB2-A03CC02254D6?download=true>. Accessed 19 April 2014
- Warhoose (2014) Zambia moves swiftly to save Kariba Dam. *Warhoose*. 24 March. <http://warhoose.com/2014/03/zambia-moves-swiftly-to-save-kariba-dam/>. Accessed 18 April 2014
- Waterbury J (1979) *Hydropolitics of the Nile valley*. Syracuse University Press, Syracuse, NY
- Wolf AT (2000) Trends in transboundary water resources: Lessons for cooperative projects in the Middle East. In: Brooks D, Mehmet O (eds) *Water balances in the eastern Mediterranean*. The International Development Research Centre, Ottawa, ON
- Wolf AT (2005) Hydropolitical vulnerability and resilience: series introduction. In: Wolf AT, Macomber MF (eds) *Hydropolitical vulnerability and resilience along international waters: Africa*. United Nations Environment Programme, Nairobi, Kenya
- Wolf AT, Stahl K, Macomber MF (2003a) Conflict and cooperation within international river basins: the importance of institutional capacity. *Water Resour Update* 125:1–10
- Wolf AT, Yoffe SB, Giordano M (2003b) International waters: Identifying basins at risk. *Water Policy* 5(1):29–60
- World Bank (2015) *Worldwide governance indicators*. <http://info.worldbank.org/governance/wgi/index.aspx#reports>. Accessed 21 December 2015
- World Bank (2010) *The Zambezi River Basin: a multi-sector investment opportunity analysis*. The World Bank, Washington DC
- World Economic Forum (2014) *Global risks 2014, ninth edition*. World Economic Forum. http://www3.weforum.org/docs/WEF_GlobalRisks_Report_2014.pdf. Accessed 20 December 2015

- Yoffe SB, Fiske G, Giordano M, Giordano MA, Larson K, Stahl K, Wolf AT (2004) Geography of international water conflict and cooperation: data sets and applications. *Water Resour Res* 40(5):1–12
- ZAMCOM (2013) ZAMCOM forges ahead! Press release. http://www.zambezicommission.org/index.php?option=com_content&view=article&id=34:zamcom-forges-ahead&catid=14&Itemid=118. Accessed 26 April 2014
- Zeitoun M, Warner J (2006) Hydro-hegemony- A framework for analysis of trans-boundary water conflicts. *Water Policy* 8(5):435–460