SCIENCE DIPLOMACY FOR TRANSBOUNDARY WATER RESOURCE MANAGEMENT

Report to the

Water Research Commission

by

Prof Anastassios Pouris

Director: Institute for Technological Innovation, University of Pretoria

WRC Report No. 2511/1/17

ISBN 978-1-4312-0951-4

January 2018

Obtainable from

Water Research Commission
Private Bag X03
Gezina, 0031

orders@wrc.org.za or download from www.wrc.org.za

DISCLAIMER

This report has been reviewed by the Water Research Commission (WRC) and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the WRC, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

Printed in the Republic of South Africa

EXECUTIVE SUMMARY

The objective of this report is to contribute to the issues of science diplomacy related to water in the Southern African Development Community (SADC) region. Science diplomacy refers to the role of science in three dimensions of policy:

- Science in diplomacy: informing foreign policy objectives with scientific advice.
- Diplomacy for science: facilitating international science cooperation.
- Science for diplomacy: using science cooperation to improve international relations between countries. (The Royal Society 2010).

More specifically, the report investigates the extent to which science diplomacy and its current base can support transboundary water resource management in South Africa and the neighbouring states. The effort aims to identify the state of affairs in scientific and technological collaboration of South Africa with the riparian states, discuss the existing instruments (legal and financial) and develop appropriate recommendations on the basis of international good practice.

Methodologically, a multi-approach was used consisting of literature review, semi-structured interviews/ discussions, and scientometric and survey analyses. The literature review focuses on:

- A brief history of science diplomacy.
- Science diplomacy and cooperation on water issues.
- SADC and transboundary water resources.
- Science collaboration and the SADC region.

Science diplomacy has a long history and it has received particular attention recently with the American Association for the Advancement of Science (AAAS) establishing a Centre for Science Diplomacy; the United Nations General Assembly declaring 2013 as the International Year of Water Cooperation; countries increasing science diplomacy activities as they are manifested in the appointment of science diplomats; the establishment of relevant education courses and relevant conferences; the establishment of the journal *Science & Diplomacy* during 2012 signifying the birth of science policy as a scientific field; governments developing science diplomacy policies and others.

Literature indicates that while it is still too early to identify best practice in the field of science diplomacy, it is apparent that necessary preconditions include relevant scientific expertise in both partner countries and availability of funding for the support of collaboration. Moreover, policymakers have to be clear about both their strategy and who should be in charge to carry it out.

The character and uses of water resources (ranging from drinking to navigational uses, and from irrigation to electricity production) elevate the importance of science diplomacy in the domain of water. The Water Conflict Chronology Database lists violence over water going back nearly 5000 years. South Africa also appears in the database for its involvement in the Lesotho coup, which led to the signing of the water agreement between the two counties.

The literature identifies that active water cooperation between countries reduces the risk of war in general. It is emphasised that cooperation is active only when there is verifiable joint management of water resources. The Intelligence Community Assessment (2012) report concludes that:

> "*During the next 10 years, many countries important to the United States will experience water problems – shortages, poor water quality, or floods – that will risk instability and state failure, increase regional tensions, and distract them from working with the United States on important US policy objectives. Between now and 2040, fresh water availability will not keep up with demand absent more effective management of water resources. Water problems will hinder the ability of key countries to produce food and generate energy, posing a risk to global food markets and hobbling economic growth. As a result of demographic and economic development pressures, North Africa, the Middle East, and South Asia will face major challenges coping with water problems*".

The report suggests that from now through 2040, improved water management (such as pricing, allocations, and virtual water trade) and investments in water-related sectors (such as agriculture, power, and water treatment) will afford the best solutions for water problems.

The Water Framework Directive of the European Union (EU) is considered good practice. Under the Water Framework Directive, all river catchments (rivers, streams, lakes and the land that drains into them) are assigned to administrative river basin districts (RBDs) by member states. Member states are required to produce river basin management plans for all RBDs in the EU. The planning process includes doing an economic analysis of all the water uses in each district, as well as determining the pressures and impacts on the water environment.

Section 3.3, namely, SADC and Transboundary Water Resources, identifies that a number of SADC countries share certain characteristics related to water and shared resources. For example, the four most water-constrained countries on the wrong side of the global average isohyet of 860 mm/yr^{-1} – Botswana, Namibia, South Africa and Zimbabwe – are also the countries who share the largest number of transboundary aquifers – Botswana (eight), Namibia (six), South Africa (nine) and Zimbabwe (four).

Elaboration of the relevant agreements governing the SADC riparian states identifies that 12 rivers with all riparian states members of SADC follow the SADC Water Protocol. The SADC Water Protocol is widely regarded as being one of the most significant examples of regional cooperation over water.

Additional regimes contribute to the governance of the various basins. Turton et al. (2008) identify that the Inkomati river basin with three riparian states (South Africa, Swaziland and Mozambique) has at least seven basin-specific regimes, four non-basin-specific regimes and one non-aggression pact. Similarly, the Limpopo river basin with four riparian states (South Africa, Zimbabwe, Botswana and Mozambique) is managed by eight basin-specific regimes and six non-basin-specific regimes. Finally, the Orange River basin with riparian states – Lesotho, South Africa, Botswana and Namibia – is governed on the basis of nine different regimes. The authors conclude that water resource management in transboundary river systems is not a major driver of conflict in the SADC region.

The next section elaborates on issues related to science collaboration in the SADC region. South Africa has a number of cooperation agreements with SADC countries. It is noted that the existing agreements, managed by the Department of Science and Technology (DST), although not focused on water, refer to water in certain occasions. Examples are water and sanitation in the agreement with Angola; efficient irrigation and water recycling with Botswana; aqua resources with Malawi; and others.

A discussion with National Research Foundation (NRF) officials showed that there is limited effort to implement the agreements. For example, the NRF opened only one call during 2016 for collaboration with Namibia. It was also indicated that the DST is considering establishing programmes with other SADC countries. Examination of the followed funding approach revealed the following:

- The effort supports pre-existing relationships. If there is no partner, there are no funds to support the creation of a relationship.
- The programme supports only academic collaborations.
- The programme does not support long-term efforts as they manifest in the exchange of students, bursaries etc.
- There are no incentives through the availability of consultation and management fees.
- Each country supports its own researchers. Hence, the relationship is symmetrical in terms of funding.

As far as research collaboration in Africa is concerned, the relevant literature provides evidence that there is minimal inter-Africa collaboration. Similarly, it has been argued that countries with financial and scientific resources dominate the collaborative efforts in the continent. In the SADC region, South Africa dominates the regional economy and regional scientific system. Currently there are no efforts to improve collaboration in the region even though the recent South Africa–Namibia collaboration programme indicates that there is demand for such activities.

Table ES1 provides information related to water publications in the SADC region for the period 2012–2014 using the Web of Science. The table shows that South Africa produces most of the research (80%) and water-related papers (75.5%) in the region. It is argued that assuming a priori that a broad research domain, like “water”, requires at least 50 publications per year to maintain some “critical mass”, it becomes apparent that only South Africa fulfils this criterion of critical mass. Furthermore, the share of water-related publications in the SADC countries shows that some countries (Zimbabwe, Malawi, Botswana, Mozambique, Namibia, and Swaziland) produce a share of water publications well above the SADC average of 1.6%. This can be interpreted that the issue is not lack of water research but a lack of research in general.

Table ES 1: Number of total and water-related publications in SADC

		2012–2014	
Countries	**No. of Papers**	**No. of Water-Related Papers**	**% of Water-Related Papers**
South Africa	45 378	702	1.5
Tanzania	2 911	54	1.8
Zimbabwe	1 306	47	3.5
Malawi	1 358	37	2.7
Zambia	1 111	5	0.4
Botswana	943	31	3.2
Congo	523	6	1.1
Mozambique	618	13	2.1
Namibia	531	20	3.7
Mauritius	481	3	0.6
Angola	171	0	0.0
Swaziland	139	3	2.1
Seychelles	128	2	1.5
Lesotho	95	3	3.1
Madagascar	757	3	0.4
Total	**56 450**	**929**	**1.6**

Setting the above in the South African context shows that the South Africa–SADC co-authorship is a small percentage (6.4%) of South Africa’s co-authorship population (52%). Furthermore, it seems that the South Africa–SADC co-authorship activities are fuelled by international efforts as only 2.4% of South African co-authored activities are between South Africa and SADC countries without non-African participants.

Identification of the research priorities areas when collaboration includes non-African participants and when there are no non-African participants shows that the co-authorship priorities change. When there are non-African participants among the authors, medical and health issues dominate the co-authorship list. When there are only authors of the African continent, the top disciplines are agriculture and environmental sciences ecology. It is argued that the non-African participants have particular priorities and influence the collaborative effort.

Table ES2 shows the number of total co-authored publications and those on water between South Africa and the other SADC countries. South Africa collaborated mostly with Zimbabwe, Tanzania and Malawi from 2012 to 2014. The Water Resources column shows that there is generally hardly any collaboration in the field. South Africa collaborates slightly with Zimbabwe and Namibia in the field.

Table ES 2: Number of co-authored publications in South Africa and other SADC countries

	2012–2014	
Country (with South Africa)	**All Documents**	**Water Resources**
Angola	10	0
Botswana	186	9
Congo	46	0
Lesotho	25	0
Madagascar	47	0
Malawi	229	5
Mauritius	42	0
Mozambique	97	0
Namibia	221	12
Seychelles	13	0
Swaziland	60	0
Tanzania	265	2
Zambia	188	0
Zimbabwe	404	19

The SADC collaboration matrix in (Table 12) water-related research reveals that there is minimal, if any, collaborative research on the topic among the other SADC countries as it is manifested in publications indexed in the Web of Science.

The main organisations cooperating in the South Africa–SADC publications are the University of Cape Town and the University of the Witwatersrand with approximately 19% of the total collaboration each. The University of KwaZulu-Natal and University of Pretoria follow on the list. The universities of Zimbabwe and Malawi are the top contributors in the South Africa–SADC collaboration from the SADC region.

A survey among South African researchers collaborating on water issues with colleagues abroad was undertaken to identify factors that affect positive or negative research collaboration in the SADC region. Thirty-four usable questionnaires were received for a return rate of just below 41%.

Respondents were asked if they consider that research collaboration in the field of water is desirable. All respondents declared that they thought that research collaboration in the field is necessary.

The respondents indicated that availability of funds for collaboration is critical for collaboration. Pre-established relationship with partners was identified as a facilitating factor for collaboration. Thirty of the participants mentioned that pre-established relationship was average in their effects on collaboration or were facilitating collaboration. Advice from funding bodies or from their own institutions was also considered to facilitate collaboration.

The respondents were asked to suggest other factors that may facilitate or inhibit collaboration. Some of the suggestions were:

- Prioritisation of the issue at government level.
- Reliable regional database of water resources.
- Academia to drive the collaborative effort.
- Availability of suitable postgraduate students from the collaborator's country.

Hindering factors were identified as:

- The lack of infrastructure and credible partners in Africa.
- Lack of available hydroclimatic data.
- South Africa's image as the "guiding" country in the region.

A number of additional suggestions were advanced. Most of the suggestions revolved around prioritising water research at national levels and providing financial and informational support.

The report advances the following recommendations:

- The Water Research Commission (WRC), DST, The Department of Water and Sanitation and the Department of Foreign Affairs in conjunction with the SADC secretariat and the relevant countries should aim to create a Common Water Research Area in the SADC region. The effort could aim to imitate the European Research Area and it could be the first step towards an SADC Research Area.
- The WRC should consider the identification of international and national resources to establish water-related research capacity in the neighbouring countries.
- The WRC has the opportunity to provide leadership in the SADC region the same way that it provides leadership in South Africa. Institutionalisation of international collaboration should be considered within WRC.
- DST and the NRF should consider enlarging the established and planned collaboration instruments to include seed funding to establish new partnerships; support for bursaries; postgraduate grants and similar.
- The WRC should consider developing an information database including the names and particulars of all researchers with publications/expertise in the field of water in the SADC. The database should aim to facilitate the identification of researchers with particular water expertise in the region. The database should be publicly available and be updated regularly.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

AAAS	American Association for the Advancement of Science
BMBF	The Federal Ministry of Education and Research
CERN	Conseil Européen Pour la Recherche Nucléaire
CNRS	Centre National de la Recherche Scientifique (The French National Center for Scientific Research)
DST	Department of Science and Technology
DWS	Department of Water and Sanitation
EU	European Union
GDP	Gross Domestic Product
ICSU	International Council for Science
IGRAC	International Groundwater Resources Assessment Centre
IKS	Indigenous Knowledge Systems
NIH	National Institutes of Health
NRF	National Research Foundation
RBD	River Basin District
RBMP	River Basin Management Plan
SADC	Southern Africa Development Community
STI	Science, Technology and Innovation
UK	United Kingdom
UN	United Nations
UNCTAD	UN Conference on Trade and Development
UNESCO	United Nations Educational, Scientific and Cultural Organisation
USA	United States of America
WFD	Water Framework Directive
WRC	Water Research Commission

1 INTRODUCTION

Science diplomacy – the use of scientific collaborations among nations to address common problems and to build constructive international partnerships – has a long history. Civilian scientific exchanges between the United States of America (USA) and the then Soviet Union throughout the Cold War provide an example of science diplomacy. Similarly, the establishment of the International Council for Science (ICSU) and CERN (Conseil Européen pour la Recherche Nucléaire) is the result of such initiatives.

Science diplomacy as a concept is in its infancy, which usually refers to the role of science in three dimensions of policy:

- Science in diplomacy: informing foreign policy objectives with scientific advice.
- Diplomacy for science: facilitating international science cooperation.
- Science for diplomacy: using science cooperation to improve international relations between countries (The Royal Society 2010).

All three dimensions are affected and based on scientific collaboration, for example, it will be impossible to use science cooperation to improve international relations if there is no scientific cooperation.

The field received particular attention recently. The reputable American Association for the Advancement of Science (AAAS) founded the Canter for Science Diplomacy in the fall of 2008 to advance the overarching goal of using science and scientific cooperation to promote international understanding and prosperity by providing a forum for scientists, policy analysts and policymakers where they can share information and explore collaborative opportunities.

In the field of water, developing approaches that balance interdependencies of transboundary waters is a matter of high importance internationally. The United Nations (UN) General Assembly, in recognition of the importance of transboundary waters, developed Resolution 65/154 and declared 2013 as the International Year of Water Cooperation. Tensions between riparian nations over transboundary waters not only affect the management of the shared sources, but they can also limit prospects for regional integration, trade and stability. This limits the potential for sustainable development to materialise.

The UN Educational, Scientific and Cultural Organization (UNESCO) among the "Key messages on promoting cooperation and preventing conflicts in international freshwater management" (Mostert 2003) argues that joint or internationally coordinated research can improve the scientific-technical quality of international agreements, prevent conflict and shape the way for appropriate management of the shared resources.

Science-based controversies can play an important role in the management of transboundary waters. However, research is rarely completely objective. Data availability, biases of modelling approaches etc. create legitimate uncertainty. Consequently, research conducted by or on behalf of one party may not always be accepted by other parties. They may either challenge the data or interpretations or – especially if they have limited scientific expertise and lack funds to hire it – opt for a highly-politicised approach to the issue at stake (Frankena 1988; Jasanoff 1990).

As South Africa has several transboundary aquifers with Botswana, Namibia, Mozambique, Zimbabwe, Lesotho and Swaziland (IGRAC 2014), the Water Research Commission (WRC) (in recognition of that importance) has established Programme 4: Transboundary Water Resources (Thrust 1) and a number of reports (Breen et al. 2013; Jacobs & Nienaber 2011; Schreiner et al. 2011) addressed aspects of the transboundary water issues.

The objective of this document is to contribute to the above issues by investigating the extent to which science diplomacy and its current base can support transboundary water resource management in South Africa and the relevant states. More specifically, the effort aims to identify the state of affairs in scientific and technological collaboration of South Africa with the riparian states, discuss the existing instruments (legal and financial) and develop appropriate recommendations on the basis of international best practice.

2 METHODOLOGY

The objectives of the investigation determine to a large extent the methodology to be followed. A multi-approach is proposed to be used consisting of a literature review, semi-structured interviews, scientometrics and survey analysis.

The review of the relevant literature related to science diplomacy in general and in relation to transboundary issues more specifically will be undertaken through a literature review. There is substantive literature in both topics [such as Altchenko & Villholth (2013); Flink & Schreiterer (2010); Puri & Aureli (2005)]. Emphasis will be placed on lessons learned.

The review of the existing agreements between South Africa and the riparian countries with emphasis on scientific and technical content will be undertaken by analysing relevant agreements. South Africa has signed bilateral agreements with 40 other African countries since 1994. Here bilateral agreements include all official intergovernmental agreements and memoranda of understanding, but do not include declarations and letters of intent. There have been 356 such agreements signed, of which 50 have significant science and technology content. These agreements will be analysed for explicit emphasis on water issues and the relevant ones will be summarised.

The extent of their implementation will be identified by interviewing officials of relevant implementing organisations such as the National Research Foundation (NRF), WRC, Department of Science and Technology (DST), and analysing their implementation approaches (as available).

Following international best practice, evaluative scientometric analysis will be employed to identify the state of scientific/research capabilities related to water research in South Africa and the related riparian states. Similarly, scientometrics will be used to identify the existing collaborative efforts between South African researchers and those in neighbouring countries across all scientific disciplines in general and in water-related research in particular (co-authorship analysis).

Scientometrics is a tool by which the state of science and technology can be observed by the overall production of scientific literature and patents at a given level of specialization. It is a well-developed scientific discipline (Pouris 2012) with its own journals (e.g. International Journal of Scientometrics) and international conferences. It provides an approach for situating a country in relation to the world, an institution in relation to a country, and even individual scientists in relation to their own peers. Scientometric indicators are equally suitable for macro-analysis (e.g. a given country's share in global output of scientific literature over a specified period) and micro-studies (e.g. a given institute's role in producing articles in a particular field or specialty of science).

The Thomson Reuters databases will be used as they cover all important journals in the world and the South African government provides incentives/subsidies for publications indexed by those databases. The databases cover different types of document such as articles, proceedings papers, book chapters, meeting abstracts, and editorial material. It is emphasised that there may be other types of collaboration that are not captured in peer-reviewed publications, but such relations will constitute the subject matter of a separate investigation.

Literature review will be employed to identify international best practice in the promotion of scientific and technological collaboration and examples of successful international efforts will be identified and be provided.

Finally, a survey approach will be used to identify challenges/obstacles in the promotion of collaboration among researchers in riparian countries. Researchers will be identified from the WRC and the Thomson Reuters databases. A questionnaire will be developed and used to collect challenges and obstacles as they are identified by relevant researchers. Researchers will be identified as those with international collaborative activities and those without.

In summary, the investigation will employ different approaches such as a literature review, semi-structured interviews, scientometrics and survey analysis. The above will lead to appropriate recommendations.

3 LITERATURE REVIEW

This chapter elaborates on four issues – a brief history of science diplomacy; science diplomacy and cooperation on water issues; the Southern African Development Community (SADC) and transboundary water resources and science collaboration and the SADC region. In each section, there is a brief summary of main findings.

3.1 Science Diplomacy: A Brief History

Science diplomacy in various formats has a long history. Before the term science diplomacy was coined, such initiatives were often called “smart power” or “soft power” by those in the field (Nye 2004). Science has several advantages in this context: it addresses important national and international issues; it is apolitical; it is based on transparency, peer review and quantitative approaches; and it provides accessibility to the world’s best minds and ideas.

As we already mentioned, science diplomacy refers to three issues:

- Science in diplomacy: informing foreign policy objectives with scientific advice.
- Diplomacy for science: facilitating international science cooperation.
- Science for diplomacy: using science cooperation to improve international relations between countries (The Royal Society 2010).

The appointment of the Foreign Secretary of The Royal Society in 1723 is probably the first recorded official appointment in the field. The role of the Foreign Secretary was to keep regular correspondence with scientists internationally and inform appropriately the Society’s Fellows about ideas and findings.

During 1941, the United Kingdom Government appointed a Director of the Central Scientific Office in Washington. His objective was to collaborate with USA research bodies and facilitate the exchange of scientific information. Similarly, a British Scientific Mission was established in China.

During 1955, Einstein and Russell published a manifesto calling scientists of all political persuasions to address the threat posed by the advent of nuclear weapons. During 1957, the first Pugwash Conference on Science and World Affairs took place. The Pugwash forum is an important one on issues of peace, nuclear non-proliferation and security. The forum was recognised by the Nobel Peace Prize in 1995.

During the 1980s, the US National Academy of Sciences and the Soviet Academy of Science ran parallel committees on international security and arms control. The collaboration of these committees has been credited with laying the groundwork for eventual dialogue between Presidents Reagan and Gorbachev.

In a 1985 address to the nation, days before meeting with Soviet leader Mikhail Gorbachev for the first time, President Ronald Reagan stated, “*We can find as yet undiscovered, avenues where American and Soviet citizens can cooperate fruitfully for the benefit of mankind … In science and technology, we could launch new joint space ventures and establish joint medical research projects*.” (Turekian & Neureiter 2012).

During the 2000s, there has been an increase in science diplomacy activities as they manifest in the appointment of science diplomats, the establishment of relevant education courses and relevant conferences.

London, Beijing, Washington, New Delhi and Pretoria host science attachés from many developed and developing economies.

The UN Conference on Trade and Development (UNCTAD) agreed in 2001 to set up a science diplomacy initiative to improve “*the provision of science and technology advice to multilateral negotiations and the implementation of the results of such negotiations at the national level*” (UNCTAD 2003).

In 2008, the AAAS in the USA established its Centre for Science Diplomacy to bring together science, foreign policy and public policy communities to identify areas where science cooperation can help build trust and foster intercultural understanding (AAAS 2009). Since 2012, the Centre has published the quarterly journal *Science & Diplomacy*. To the extent that a dedicated journal signifies the birth of a new scientific discipline, 2012 is the birth year of science policy.

Similarly, the National Science Board issued a policy paper under the heading, "International Science and Engineering Partnerships: A Priority for US Foreign Policy". The paper argued that the government's continued neglect of science and technology in foreign policy and the excessive security curbs it had imposed on academic exchanges in the wake of 9/11 would thwart and eventually squander the country's scientific excellence, global pole position in science and technology and innovation base.

During 2009, President Obama called for a partnership during his "A New Beginning" speech in Cairo, Egypt. These partnerships would include a greater focus on engagement of the Muslim world through science, technology, and innovation (White House 2009).

Japan has had a formal policy on science diplomacy since 2008 (Toward the Reinforcement of Science and Technology Diplomacy). It identifies four objectives (Japanese Council for Science and Technology Policy 2008):

- Negotiating the participation of Japanese scientists in international research programmes.
- Providing scientific advice for international policymaking.
- Helping to build science capacity in developing countries.
- Using science to project power on the international stage, so that Japan's prestige increases, and the country attracts inward investments.

Switzerland provided for joint science and technology programmes with researchers and companies from "target regions" outside of Europe and the USA for the first time in its four-year plan for education, research and innovation 2008–2011. The Swiss Foreign Service is tasked with assisting these objectives.

On 12 March 2010, Congressmen H. Berman and J. Fortenberry in the USA introduced the "Global Science Programme for Security, Competitiveness, and Diplomacy Act" (Govtrack.US 2010), which proposed an increase in the application of science and scientific engagement in America's foreign policy. The Act postulated that "*the programme shall carry out, through the provision of grants, the following activities:*

(1) Collaborative research

(A) In general

Establish global research competitions that will undertake the following:

(i) Address the following global challenges: ocean acidification, non-proliferation, multiple drug resistant diseases, waterborne diseases, development of sustainable renewable energy resources, sanitation, food shortage, and water resources.

(ii) Engage former weapons of mass destruction scientists to assist in their transition to peaceful, civilian research.

(iii) Provide incentives for United States businesses to undertake programmes employing such scientists for peaceful purposes.

(iv) *Foster stronger partnerships and relations between United States and foreign universities in science and technology*."

An article (Flink & Schreiterer 2010) investigated the approaches followed in the science diplomacy (objectives, priorities, programmes and resources) of France, Germany, Japan, Switzerland, the United Kingdom (UK) and the USA. The findings were revealing. The authors establish that:

"*On the one hand, somehow or other, all countries have taken an active stand and initiated new policies, tools and practices, and mobilised extra resources to better serve these issues. On the other hand, their individual perspectives, approaches, and practices differ widely from one another. In stark contrast to more conventional policy fields, there is no such thing as an acknowledged state of the art of how to do SD (science diplomacy) or a consensus on what science diplomacy could or should be – at least not as yet*." (ibid: p. 675).

Furthermore, the article states:

"*The two most important lessons are fairly simple: To be successful in doing science diplomacy by any measure, a country has to be very clear about both its overall strategy and who should be in charge to carry it out. Often times, potential partners abroad do not know what is being offered to them and to whom they can turn with questions, project proposals, or grant applications.*

Second, exploiting science for political purposes — to brag about competence in hot high-tech fields or research areas or to demonstrate goodwill in international relations – makes little or no sense. For collaboration to take off and become gratifying for all participating parties, it is vital to engage the curiosity and interests at least of those scientists who are considered to run the collaborative programme or venue. 'Systemic' strategies need not only to be compatible with bottom-up project proposals, informal ties and academic interests, but also have to make them fit in." (ibid: p. 676)

Of course, science collaboration and diplomacy are not without its barriers. Probably the most important constraint is asymmetry in capabilities. You cannot promote collaboration if one of the partners does not have the relevant expertise. This is a particular concern in South Africa as all SADC countries are very small in terms of scientific and technological expertise.

Matching priorities in the different partners and making available funding are also relevant issues. Finally, to a limited extent there may be concerns related to security (e.g. technologies, exports etc.).

To summarise: science diplomacy, although it has a long history, has a recent birth (2012) as a scientific discipline. The concept refers to three issues:

- Science in diplomacy: informing foreign policy objectives with scientific advice. Examples may include environmental and health issues where multiparty collaboration is necessary.
- Diplomacy for science: facilitating international science cooperation.
- Science for diplomacy: using science cooperation to improve international relations between countries.

While it is still too early to develop best practice in the field, it is apparent that necessary preconditions include relevant scientific expertise in both partners. To promote science diplomacy, stronger partners should help to build science capacity in weaker countries and foster closer collaboration. Better coordination of government science activities locally (and particularly international science activities) can also contribute to the objectives of science diplomacy. Possible obstacles include the non-availability of funding for planned activities; matching of priorities in the partners; and issues of security.

3.2 Science Diplomacy and Cooperation in Water

The character and uses of water resources (ranging from drinking to navigational uses, and from irrigation to electricity production) elevate the importance of science diplomacy in the domain.

The term "water conflict" was coined to describe conflict between countries, states or groups over an access to water resources. While the conflicts may be over salt or fresh water, conflicts occur mostly over fresh water because freshwater resources are necessary, yet limited; hence, they are the centre of water disputes arising out of need for potable water and irrigation.

An online database of water-related conflicts – the Water Conflict Chronology – was developed by the Pacific Institute (2016). The database lists violence over water going back nearly 5000 years. South Africa also appears in the database (1986). It states:

"*South Africa supports a bloodless coup by Lesotho's defence forces. Immediately afterward, the two countries agree to share water from the Highlands of Lesotho, following 30 years of unsuccessful negotiations. There is disagreement over the degree to which water was a motivating factor for either party*".

A recent report, "Water Cooperation for a Secure World" (Strategic Foresight Group 2013) concluded after examining transboundary water relations in over 200 shared river basins in 148 countries who active water cooperation between countries reduces the risk of war in general. The authors argue that "*Water is not only about development and health. Water is also about security of people and nations*" (ibid: p. 1).

It should be emphasised that "active water cooperation" does not mean the mere signing of a treaty for the allocation of water, or for data exchange, or for the establishment of a river basin organisation. The cooperation is active only when there is verifiable joint management of water resources. The Strategic Foresight Group (2013) argues that:

"*Active water cooperation means commitment of riparian countries to most of the following activities, or more, where such commitment is translated into action programmes implemented with agreed time frames or on an on-going basis.*

- *Joint management of the water body with decision-making authority on water allocation and resource management submitted to a river basin organisation.*
- *Joint investment programme and joint decision-making on allocation of financial resources pertaining to projects to accrue benefits from the river or lake.*
- *Joint management of flood control.*
- *Coordination of water quality and reduction of pollutants to harmonise quality between countries.*
- *Joint programme of action for environmental protection of water body with deadlines which are implemented.*
- *Consultation between riparian countries on construction of dams or reservoirs with data exchange accepted by all countries or joint construction and management of dams.*
- *Joint management of water flows in all their aspects*." (ibid: p. 4).

During 2012, the Intelligence Community Assessment (2012) investigated how water issues will affect USA interests up to 2040. The report concludes that:

"*During the next 10 years, many countries important to the United States will experience water problems—shortages, poor water quality, or floods—that will risk instability and state failure, increase regional tensions, and distract them from working with the United States on important US policy objectives. Between now and 2040, fresh water availability will not keep up with demand absent more effective management of water resources. Water problems will hinder the ability of key countries to produce food and generate energy, posing a risk to global food markets and hobbling economic growth. As a result of demographic and economic development pressures, North Africa, the Middle East, and South Asia will face major challenges coping with water problems*".

Furthermore, the Intelligence Community Assessment (2012) report states:

"*We assess that a water-related state-on-state conflict is unlikely during the next 10 years. Historically, water tensions have led to more water-sharing agreements than violent conflicts. However, we judge that as water shortages become more acute beyond the next 10 years, water in shared basins will increasingly be used as leverage; the use of water as a weapon or to further terrorist objectives also will become more likely beyond 10 years*" (ibid: p. 3).

The report also identifies that once cooperative water agreements are established through treaties, they are often resilient over time and produce peaceful cooperation – even among other existing hostilities and contentious issues.

About Southern Africa it mentions that "*almost certainly will suffer a decrease in water resources due to climate change*" (ibid: p. 1).

The report suggests that from now through 2040, improved water management (e.g., pricing, allocations, and "virtual water" trade) and investments in water-related sectors (e.g., agriculture, power, and water treatment) will afford the best solutions for water problems (Intelligence Community Assessment 2012).

Because agriculture uses approximately 70% of the global freshwater supply, the greatest potential for relief from water scarcity will be through technology that reduces the amount of water needed for agriculture (ibid: p. 6). The use of large-scale irrigation systems and research to develop drought-resistant or salt-tolerant crops are suggested as possible solutions.

As far as particular technologies are concerned, the authors state:

"*Given the low price of water charged in most regions of the world, users are less motivated to adopt technologies such as desalination and drip-irrigation systems. For industry and households, water prices in developed countries range from $0.60/cubic meter to more than $3/cubic meter. Water for agriculture in most countries is priced at approximately $0.10/cubic meter. Recent data indicate that desalination processes produce water at much higher costs: $0.61/cubic meter for reverse osmosis, and $0.72/cubic meter to $0.89/cubic meter for thermal processes*." (ibid: p. 9)

In summary, the report recommends adopting pricing mechanisms and policies to encourage efficient water use and hydrological modelling for new and revised water-sharing agreements. They suggest that the expertise of USA can be used internationally to resolve water issues challenges nationally and internationally.

It is interesting to note the way the European Commission manages river basins. The main instrument is the European Union (EU) Water Framework Directive (WFD) (2000/60/EC). The directive seeks to protect, improve and maintain the environmental condition of surface and ground waters (POST 2008).

Under the WFD, all river catchments (rivers, streams, lakes and the land that drains into them) are assigned to administrative river basin districts (RBDs) by member states. Within in each RBD, "water bodies" must be identified as groundwater or as discrete and significant elements of surface water (rivers, lakes, canals, estuaries and coastal waters). Protected areas are defined as all those water-dependent areas that are designated under other EU directives (such as the Habitats Directive 92/43/EEC).

Member states were required to produce river basin management plans (RBMPs) for all RBDs in the EU by 2009 (WFD Articles 11 and 13). The planning process included doing an economic analysis of all the water uses in each RBD, as well as determining the pressures and impacts on the water environment. The RBMPs set out environmental objectives for all groundwater and surface water bodies and protected areas within an RBD. The plans included programmes of measures to meet these objectives.

The approach solves to a certain extent the challenges of spatial fit. By orienting water management around river basins, the approach expects to remedy the challenges of disparities between functional space and political territory by encouraging a more holistic and territorially integrated approach to solving water-related problems. This agrees with Holzinger (2000) who argues that disparities between functional space and political territory can only be removed by the reorganisation of political territories or by functional cooperation between the responsible jurisdictions.

While the approach has a substantial beneficial bearing on institutional aspects of water management, there are additional challenges. Most experts agree that meeting the letter and spirit of the WFD will require interactive governance not only between water managers in different locations but also between them and, for example, those responsible for regulating land use (Moss 2004).

Several activities such as land use planning, agriculture and forestry, hydro-electric power, navigation, nature conservation and economic development have an impact on water use and quality and they are not under the control of the water bodies.

Thus, collaboration, science and diplomacy are particularly important for water issues. The online database of water-related conflicts and interest of the intelligence community in the USA to investigate future conflicts related to water are indications of the importance of the issue. The WFD in the EU is an attempt to resolve the disparities between functional space and political territory in the region.

3.3 SADC and Transboundary Water Resources

The SADC region includes 12 mainland states and two islands. The mainland states are linked by 21 river basins that cross international borders. The region also includes 22 known transboundary aquifer systems. Figure 1 shows a schematic representation of the distribution of water resources – surface and groundwater – across the SADC region.

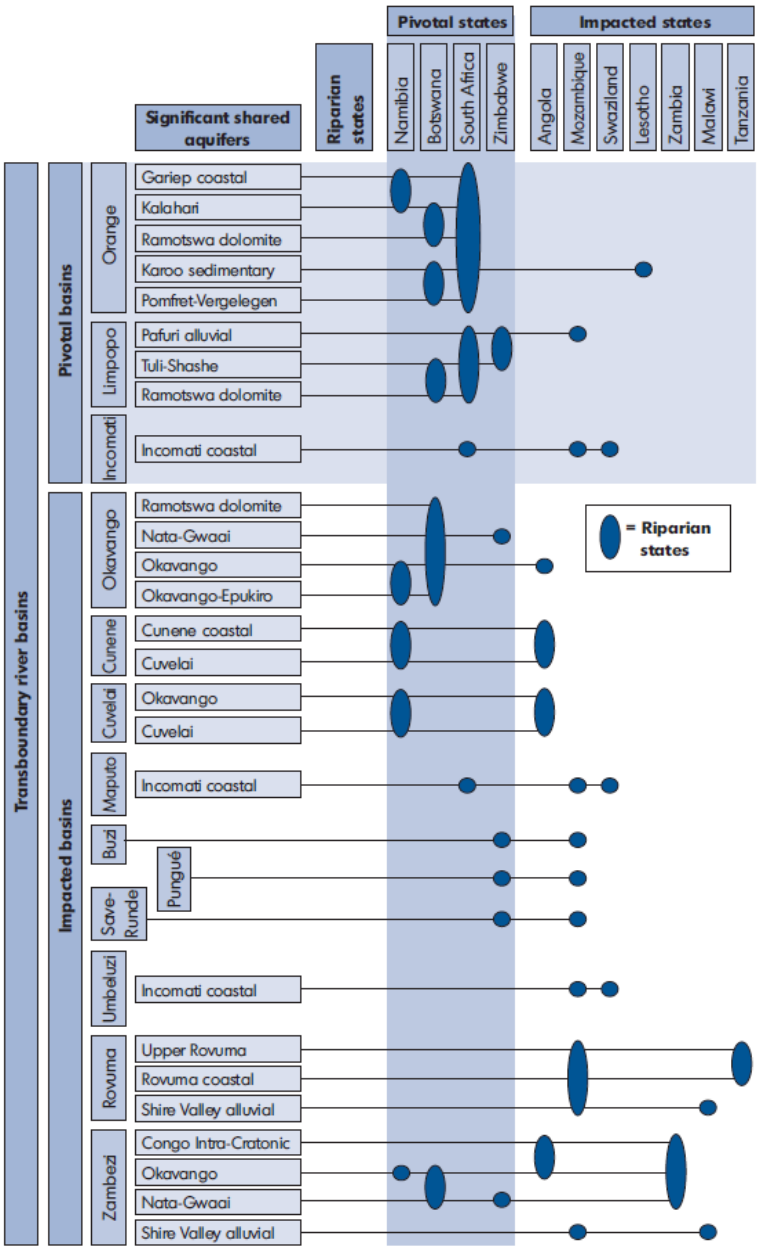

Figure 1: Representation of water resources and management units in SADC

Source: Turton et al. 2008.

While investigating issues of water governance in SADC, Turton (2010) states that:

"*It is significant to note that the four most water-constrained countries that are on the 'wrong side' of the global average isohyet of 860 mm/yr^{-1} — Botswana (400 mm/yr^{-1}), Namibia (254 mm/yr^{-1}), South Africa (497 mm/yr^{-1}) and Zimbabwe (652 mm/yr^{-1}) — are also the countries that share the largest number of transboundary aquifers — Botswana (8), Namibia (6), South Africa (9) and Zimbabwe (4). These four countries are called pivotal states, and the three transboundary surface water basins that they depend on for strategic supplies of water, and which have already been fully — or almost fully — allocated (Inkomati, Limpopo, Orange/Senqu), are called pivotal basins*" (ibid: p. 12).

Table 1 shows the 21 transboundary river basins in the SADC. The table also indicates the existence of interstate agreements, the names of the respective riparian states and the classification in terms of being either perennial (permanently flowing) or endorheic (draining inland rather than into the sea).

Table 1: Transboundary river basins within the SADC

Basin name	Agreement	Type	Riparian states
Buzi	No	Perennial	Mozambique, Zimbabwe
Chiloango	No	Perennial	Angola, Democratic Republic of Congo (DRC)
Congo	Yes	Perennial	Angola, Tanzania, Zambia
Cunene	Yes	Perennial	Angola, Namibia
Cuvelai	Yes (no RBO[a])	Endorheic	Angola, Namibia
Incomati	Yes	Perennial	Mozambique, South Africa, Swaziland
Lake Chilwa	No	Endorheic	Malawi, Mozambique
Lake Natron	No	Endorheic	Kenya, Tanzania
Limpopo	Yes	Perennial	Botswana, Mozambique, South Africa, Zimbabwe
Maputo	Yes	Perennial	Mozambique, South Africa, Swaziland
Nile	Yes	Perennial	DRC, Kenya, Tanzania
Okavango/ Makgadikgadi	Yes	Endorheic	Angola, Botswana, Namibia
Orange/Senqu	Yes	Perennial	Botswana, Lesotho, Namibia, South Africa
Pagani	No	Perennial	Kenya, Tanzania
Pungué	No	Perennial	Mozambique, Zimbabwe
Rovuma	Yes (no RBO[a])	Perennial	Mozambique, Tanzania
Savé–Runde	No	Perennial	Mozambique, Zimbabwe
Thukela	No	Perennial	Lesotho, South Africa
Umba	No	Perennial	Kenya, Tanzania
Umbeluzi	Yes	Perennial	Mozambique, South Africa, Swaziland
Zambezi	Yes	Perennial	Angola, Botswana, Malawi, Mozambique, Namibia, Zambia, Zimbabwe

Source: Turton et al. 2008.

Next, we elaborate on the agreements governing the SADC riparian states.

Twelve rivers with all riparian states members of the SADC follow the SADC Water Protocol. The SADC Water Protocol (SADC 1995), known officially as the Protocol on Shared Watercourse Systems, was the first regional agreement signed by all SADC member states after South Africa joined that grouping. It was influenced by aspects of international water law in existence at the time, such as the Helsinki Rules, the Dublin Principles and Agenda 21, and as such, it represents a regional consensus over core principles enshrined in these various legal threads. The SADC Water Protocol is widely regarded as one of the most significant examples of regional cooperation over water.

Additional regimes contribute to the governance of the various basins. Turton et al. (2008) identify that the Inkomati river basin with three riparian states (South Africa, Swaziland and Mozambique) has at least seven basin-specific regimes, four non-basin-specific regimes and one non-aggression pact. Similarly, the Limpopo river basin with four riparian states (South Africa, Zimbabwe, Botswana and Mozambique) is managed by eight basin-specific regimes and six non-basin-specific regimes. Finally, the Orange River basin with four riparian states (Lesotho, South Africa, Botswana and Namibia) is governed on the basis of nine different regimes.

Turton et al. (2008) conclude that water resource management in transboundary river systems is not a major driver of conflict in the SADC region. Further, they identify three issues with the potential to trigger conflict:

- Water quality arising from waste disposal and mine closure.
- Eutrophication arising from enrichment of water by nutrient return flows.
- Inter-basin transfers that take water from donor basins and divert flows to recipient basins, reallocating wealth unilaterally.

It should be mentioned that there are several cooperative interventions in the region. Examples include the Lesotho Highlands Water Project that augments water resource availability in South Africa and generates significant public revenues for Lesotho; and the joint power generation projects between Zimbabwe and Zambia, and between Namibia and Angola that contribute to those countries electricity needs and others.

In summary, the 12 countries in mainland SADC share 21 river basins and 22 known transboundary aquifer systems. It was also noted that the countries more in need of water share the largest number of river basins and transboundary aquifer systems.

A brief review of the governance issues in the region identifies the existence of a multitude and complex system of regimes. The broad sentiment of investigators is that transboundary river systems is not a major driver of conflict in the SADC region. However, it is emphasised that future conflicts due to pollution or scarcity are possible.

3.4 Science Collaboration and SADC

Research collaboration is a sociological phenomenon given attention by researchers and governments internationally (Yeung et al. 2005). Researchers investigate the effects, modes, dynamics and motives of collaborations, while governments use research collaboration as a policy instrument for technology transfer from universities and research councils to industry (intra-collaboration); for knowledge transfer from abroad (inter-collaboration); as means to improve diplomatic relations with other countries by creating good will and gain political capital (Wagner et al. 2002), and others.

Researchers collaborate with each other for various reasons: to improve their visibility and recognition (Narin et al. 1991); to use expensive equipment and facilities that are not under their control (Schubert & Sooryamoorthy 2010); and to acquire expertise and new ideas (Beaver & Rosen 1978) needed for their research and others. Among other reasons included are historical ties; linguistic preferences; geographical proximity; and specific problem issues (e.g. disease control or natural disaster mitigation).

In the policy domain, scientific collaboration has become an important component of science, technology and innovation policy internationally with substantial resources allocated by governments for this objective. In the mid-1990s, it was estimated that the USA spent US$3.3 billion on international collaboration. Similarly, other developed countries spent substantial amounts as a percentage of their gross domestic product (GDP) (Wagner et al. 2002a).

Government involvement in collaboration programmes is based on the recognition that research does not stand alone. It is one aspect of an intensively competitive ecosystem of knowledge development and commerce. Recognition of this context sets the basis for multinational collaborations.

Different types of collaboration create different management requirements. Figure 2 presents the different types of collaboration. The figure shows two axes that can describe different organisational forms of collaboration. One axis runs from spontaneous (bottom-up) research deriving from the interests of scientists, to highly organised research defined by a funding party. The other axis defines the degree of centralisation of the effort.

These two axes form four quadrants that characterise collaborative research. Activities on the left-hand side of the diagram might be described as dynamic as the collaboration requires active learning and sharing of tasks and information among researchers who are often dispersed geographically. Activities on the right-hand side might be described as material/institutional research as collaboration relies on a shared resource or common research location. Mega-science projects could be placed in the bottom-right quadrant, namely, organised and centralised. Scientist-initiated research would be placed in the upper-left quadrant.

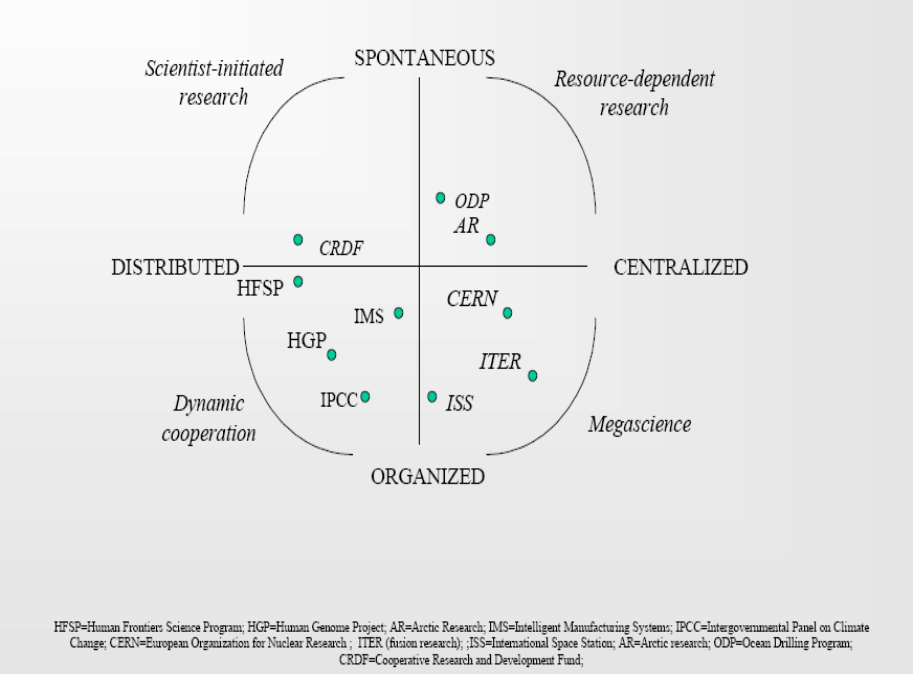

Figure 2: Types of collaboration

Source: Wagner et al. 2002.

There is a substantial literature on the topic of collaboration (Chang et al. 2013; Lee et al. 2012). However, there is limited literature about collaboration in Africa in general and SADC in particular. In this context, it is important to mention that South Africa has a number of cooperation agreements with the SADC countries. Table 2 shows the existing agreements managed by the DST. It should be noted that no agreement refers to water in their thematic focus areas[1].

[1] More detailed inspection of agreements identified that certain agreements refer to water and related areas. Examples are water and sanitation in the agreement with Angola; efficient irrigation and water recycling

Table 2: South Africa's SADC Science, Technology and Innovation Cooperation Agreements administrated by the DST

Country	Title	Year of signature	Status	Nature of cooperation activities	Thematic focus areas
Angola	Science and Technology Cooperation Agreement	2008	Active	Joint research projects; Researcher and student exchange programmes	Human Capital Development
Botswana (SKA/AVN partner)	Science and Technology Cooperation Agreement	2005	Active	Joint research collaboration	Biotechnology; Space sciences; Water Management; Mining; Energy; Food security; ICT (HPC); SKA/AVN; SADC Indigenous Knowledge Systems (IKS)
Lesotho	Science and Technology Cooperation Agreement	2005	Active	Trilateral project	Agricultural sciences
Madagascar		2015	Future	To be agreed	To be agreed
Mauritius	Science and Technology Cooperation Agreement		Future	To be agreed	To be agreed
Malawi	Science and Technology Cooperation Agreement	2007	Active	Trilateral project	ICT; Biosciences; IKS; Laser Technology; Human capital development; Science, technology and innovation (STI) policy development
Mozambique	Science and Technology Cooperation Agreement	2006	Active	Joint research collaboration	Agricultural sciences; Space sciences; ICT
Namibia	Science and Technology Cooperation Agreement	2005	Active	Joint research collaboration	Space sciences; Biotechnology; IKS; ICT; Energy; Mining geology; Agro-processing
Tanzania	Science and Technology Cooperation Agreement	2011	Active	Joint research collaboration	STI policy exchanges; ICT; Nanotechnology; IP; Biotechnology

with Botswana; aqua resources with Malawi and others. However, it should be emphasised that the NRF support is using a one-approach-fits-all method.

Country	Title	Year of signature	Status	Nature of cooperation activities	Thematic focus areas
Zambia	Science and Technology Cooperation Agreement	2007	Active	Joint research collaboration	Biotechnology; IKS; ICT; Space sciences; Mining; Astronomy
Zimbabwe	Science and Technology Cooperation Agreement	2007	Active	Joint research collaboration	Biotechnology; Human capital development; ICT; Mining; Nanotechnology

Source: Personal communication NRF.

Discussion with the NRF showed that the NRF opened only one call during 2016 for collaboration with Namibia. It was also indicated that the DST is considering establishing programmes with other SADC countries.

Appendix 1 presents a copy of the NRF call for research support for collaboration with Egypt, Kenya, Namibia, and Uganda. The call for proposals require at least one academic from each country with a PhD. The maximum amount per project is R600 000 for a three-year period. A maximum of 15 projects will be funded. Funds do not cover:

- Consultant's fees.
- Educational expenses (scholarships and/or bursaries, etc.).
- Large equipment.
- Project management fees.
- Salaries and temporary staff fees.

The above conditions reveal the limitations of the effort. These are:

- The effort supports pre-existing relationships. If there is no partner, there are no funds to support the creation of a relationship.
- The programme supports only academic collaborations.
- The programme does not support long-term efforts as they manifest in an exchange of students, bursaries etc.
- There are no incentives through the availability of consultation and management fees.
- Each country supports its own researchers. Hence, the relationship is symmetrical in terms of funding.

Furthermore, the expected impacts are not linked to funding. For example, the terms of reference state that impacts will be industrial development, possible commercialisation of research results and student involvement. However, these objectives are not supported financially and/or regulatory and, hence, should not be expected to be achieved.

The NRF informed us that 45 proposals were evaluated in the two countries. This figure indicates that there is demand for such support.

There are few articles investigating collaboration in the African continent. Sooryamoorthy (2009) investigated the collaboration patterns of South African researchers, and Boshoff (2010) identified the collaborative patterns in the SADC. Boshoff identified that, "*only 3% of SADC papers during 2005–2008 were jointly authored by researchers from two or more SADC countries (intra-regional collaboration), and only 5% of SADC papers were jointly authored with researchers from African countries outside the SADC (continental collaboration)*" (ibid: p. 481).

Similarly, Onyancha and Maluleka (2011) identified that knowledge production through collaborative research among sub-Saharan African countries is minimal.

More recently, Pouris & Ho (2014) identified the state of research collaboration in the African continent during the period from 2007 to 2011. The results are based on the analysis of more than 111 000 articles that had at least one author with a corporate address in the African continent. Estimation of the activity indices of various scientific fields shows the emphasis or under-emphasis of the various fields. The activity index is defined as the country's share in world's publication output in the given field divided by the country's/region's share in world's publication output in all science fields.

The most emphasised research fields are those of tropical medicine (12.5 times bigger than the expected from the scientific size of Africa); parasitology (6.5 times bigger) and infectious diseases (4.6 times bigger). The list of emphasised research areas is dominated by medical and natural resources fields (biodiversity; water resources; entomology; mining etc.). The activity index of water resources is 2.8. The individual African countries exhibit substantially higher collaboration patterns than European and other countries. Nigeria was the only country with a collaboration rate lower than 50%. Twenty-nine countries published more than 90% of their articles in collaboration with other countries. The authors argued that this pattern is indicative of dependency on foreign resources.

Identification of the main countries collaborating with Africa shows that the USA, France and the UK are the main collaborating partners. The authors emphasise that these countries are the most collaborative countries in the world. The USA, France and UK are also the largest funders of research in biosciences, with more emphasis on medicine and agricultural sciences in Africa. Furthermore, collaboration with non-African countries exceeds that of inter-African collaboration. Pouris & Ho (2014) state that, "*It is logical to argue that African collaboration is not driven by local researchers searching for collaborators, but by the availability of resources and interests outside the continent*".

This is of particular importance as Pouris & Ho (2014) indicate that research conditions in the continent are amenable to direction from outside interests (e.g. from South Africa).

Pouris (2010) investigated the research performance of the 15 countries in the SADC region. It was identified that South Africa with 19% of the population in the region is responsible for 60% of the regional GDP and 79% of the region's publications. All countries tend to have the same focus in their disciplinary priorities and underemphasize disciplines such as engineering, materials science and molecular biology. It was an expressed concern that the current research infrastructures are inadequate to assist in reaching the objectives developed in the Regional Indicative Strategic Development Plan of the Community.

Zdravkovic et al. (2016) through interviews in four SADC countries identified that while for the interviewed scientists working with northern scientists means better funding, more organised research, and access to different knowledge, south–south collaboration means easier contact, working on equal conditions, and solving relevant problems for Africa.

Thus, scientific collaboration is taking place internationally with several possible benefits. Motivators and enablers include greater impact; scientific discovery; scale of research projects; scope and complexity of research topics and international issues; capacity building; and advances in technology and communications. The activity has attracted the attention of researchers and scientific collaboration is the subject of research.

As far as research collaboration in Africa is concerned, the literature provides evidence that there is minimal inter-Africa collaboration. Similarly, it has been argued that countries outside Africa with resources dominate the collaborative efforts in the continent. In the SADC region, South Africa dominates the regional economy and regional scientific system. Currently there are no efforts to improve collaboration in the region even though the recent South Africa–Namibia collaboration programme indicates that there is demand for such activities.

4 SCIENTOMETRIC ANALYSIS SADC

This section provides scientometric information related to SADC countries. Emphasis is placed on water-related literature and issues of collaboration as they manifest in co-authorship.

Table 3 shows the number of papers and the number of water-related papers produced by each country from 2002–2004 and 2012–2014. South Africa produced the most research publications in both periods. That was 80% during 2012–2014 and 81.2% during the 2002–2004 period. In terms of water-related research, South Africa produced 75.5% of the water-related research during 2012–2014 and 71.8% during the 2002–2004 period.

Assuming a priori that a broad research domain such as “water” requires at least 50 publications per year to maintain some critical mass, it becomes apparent that only South Africa fulfils this criterion.

Table 3: SADC countries: number of total papers and water-related papers per country for two time periods

		2012–2014		2002–2004
Countries	**No. of Papers**	**No. of Water-Related Papers**	**No. of Papers**	**No. of Water Resources Related Papers**
South Africa	45 378	702	17 076	395
Tanzania	2 911	54	950	47
Zimbabwe	1 306	47	792	64
Malawi	1 358	37	417	5
Zambia	1 111	5	278	6
Botswana	943	31	470	15
Congo	523	6	158	2
Mozambique	618	13	144	3
Namibia	531	20	173	5
Mauritius	481	3	189	1
Angola	171	0	31	0
Swaziland	139	3	46	4
Seychelles	128	2	37	1
Lesotho	95	3	26	2
Madagascar	757	3	226	0
Total	**56 450**	**929**	**21 013**	**550**

Table 4 shows the share of water-related publications in the SADC countries for the two time periods. It becomes apparent that several countries (Zimbabwe, Malawi, Botswana, Mozambique, Namibia, and Swaziland for 2012–2014) produced a share of water publications well above the SADC average of 1.6%. This can be interpreted that the issue is not lack of water research but a lack of research in general. It should also be noted that Angola, Madagascar and Zambia produced less water-related publications than the expected from the SADC average.

Table 4: SADC countries: number of total papers and percentage of water-related papers per country for two time periods

	2012–2014		2002–2004	
Countries	**No. of Papers**	**% of Water-Related Papers**	**No. of Papers**	**% of Water Resources Related Papers**
South Africa	45 378	1.5	17 076	2.3
Tanzania	2 911	1.8	950	4.9
Zimbabwe	1 306	3.5	792	8.0
Malawi	1 358	2.7	417	1.2
Zambia	1 111	0.4	278	2.1
Botswana	943	3.2	470	3.2
Congo	523	1.1	158	1.2
Mozambique	618	2.1	144	2.1
Namibia	531	3.7	173	2.9
Mauritius	481	0.6	189	0.5
Angola	171	0.0	31	0.0
Swaziland	139	2.1	46	8.7
Seychelles	128	1.5	37	2.7
Lesotho	95	3.1	26	7.7
Madagascar	757	0.4	226	0.0
Total	**56 450**	**1.6**	**21 013**	**2.6**

It should be mentioned that during 2012–2014, the USA produced 9677 water resource publications, which constituted 0.5% of the total number of publications in the USA. Similarly, in China there were 7741 water resource publications out of 960 318 total publications, which is 0.8% of the total publications. It is apparent that after a certain threshold of number of water resource publications, the share of publications in the country's total is diminishing.

Comparing the two time periods in Table 4 shows that the share of water publications has declined in the most research prolific countries (South Africa, Tanzania and Zimbabwe). In South Africa, the water publications share declined from 2.3% during 2002–2004 to 1.2 % during 2012–2014. This is the result of the higher growth of non-water-related publications.

It is interesting to set the above figures in the context of the South African research system. During the 2012–2014 period, South African researchers produced 45 343 publications[2]. Of these, 23 581 (52%) were co-authored with at least one author from another country. Among the co-authored publications, 1505 (6.4% of the co-authored publications) had at least one co-author from the SADC region. In order to identify the influence of non-African countries in the co-authorship effort, we excluded the articles that had non-African co-authors. Hence, only 563 publications were identified to be co-authored between South African and SADC co-authors (without non-African co-authors). This is only 2.4% of the South African co-authored publications.

[2] The majority of these publications are articles (1290 or 85.7%); meeting abstracts are 79; review articles 64; book chapters 51; editorial material 38; proceeding papers 27; and others.

To summarise: South Africa–SADC co-authorship constitutes a small percentage (6.4%) of the South African co-authorship population. Furthermore, it seems that South Africa–SADC co-authorship activities are fuelled by international efforts as only 2.4% of South African co-authored activities are between South Africa and SADC countries without non-African participants.

Table 5 shows the main countries participating in the South Africa–SADC collaborative efforts. US authors participate in approximately 31% of the South Africa–SADC publications. Zimbabwe is the country who collaborates the most with South African among the SADC countries (almost 27% of all co-authored publications during the period). England, Tanzania and Malawi follow on the list.

Table 5: Main partnering countries in South Africa and SADC co-authorship 2012–2014

Country	Publications out of 1505	Percent of total
USA	466	30.9
Zimbabwe	406	26.9
England	365	24.2
Tanzania	267	17.7
Malawi	237	15.7
Namibia	221	14.6
Zambia	188	12.5
Botswana	187	12.4
Kenya	159	10.5
France	143	9.5
Australia	137	9.1

We have also identified the main funders of research as they appear in the end of the various publications. The NRF appears most often in 180 publications; Bill and Melinda Foundation follows with 72 publications; National Institutes of Health (NIH) with 64 publications; Wellcome Trust with 60 publications and The Federal Ministry of Education and Research (BMBF), The French National Center for Scientific Research (CNRS) and Max Plank Society with 32 publications each.

Table 6 shows the research areas where South Africa and SADC countries collaborate. It becomes apparent that medical and health issues dominate the co-authorship list. Water resources contribute 2.6% to the South Africa–SADC co-authorship during the period.

Table 6: Co-authored research areas 2012–2014

Research Areas	Number of Publications out of 1505
Infectious Diseases	214 (14.2%)
Immunology	160 (10.6%)
Public Environmental Occupational Health	131 (8.7%)
Environmental Sciences Ecology	130 (8.6%)
Science Technology Other Topics	109 (7.2%)
Agriculture	68 (4.5%)
Virology	64 (4.2%)
General Internal Medicine	62 (4.1%)

Research Areas	Number of Publications out of 1505
Geology	56 (3.7%)
Microbiology	49 (3.2%)
Plant Sciences	44 (2.9%)
Zoology	44 (2.9%)
Veterinary Sciences	43 (2.8%)
Tropical Medicine	41 (2.7%)
Astronomy Astrophysics	40 (2.6%)
Water Resources	40 (2.6%)
Chemistry	39 (2.5%)

Table 7 shows the main organisations cooperating in the South Africa–SADC publications. The University of Cape Town and University of Witwatersrand are on top of the list with approximately 19% of the total collaboration each. The University of KwaZulu-Natal and University of Pretoria follow. The universities of Zimbabwe and Malawi are the top contributors in the South Africa–SADC collaboration from the SADC region (not in South Africa). It is interesting to note that collaboration takes place almost exclusively among universities.

Table 7: Main cooperating organisations 2012–2014

Organisations	Number of publications out of 1505
University of Cape Town	290 (19.2%)
University of Witwatersrand	282 (18.7%)
University of KwaZulu-Natal	235 (15.6%)
University of Pretoria	206 (13.6%)
University of Zimbabwe	194 (12.8%)
Stellenbosch University	161 (10.7%)
University of London	150 (9.9%)
University of Malawi	120 (7.9%)
London School of Hygiene Tropical Medicine	108 (7.1%)
University of Namibia	95 (6.3%)
University of Botswana	90 (5.9%)
University of California System	89 (5.9%)
Harvard University	88 (5.8%)
North-West University SA	85 (5.6%)
University of Zambia	83 (5.5%)
John Hopkins University	64 (4.2%)

We have also analysed the co-authorship patterns of South Africa–SADC without non-African countries participating.

Table 8 shows the contribution of the various SADC countries in the collaborative efforts between South Africa and SADC when there are no non-African participants. Zimbabwe is the main contributor with 30.2% of the total co-authored publications. Comparison of Table 5 and Table 8 confirms that the majority of the co-authored publications include non-African participants too.

Table 8: Main partnering countries in South Africa and SADC co-authorship without non-African participants 2012–2014

Country	Publications out of 563	Percent of total
Zimbabwe	170	30.2
Namibia	89	15.8
Botswana	68	12.0
Tanzania	67	11.9
Malawi	60	10.6
Swaziland	35	6.2
Zambia	29	5.1
Mozambique	27	4.8
Mauritius	23	4.0

Table 9 shows the most prolific research areas in the cooperation efforts. Agriculture and environmental sciences ecology are on top of the list. It is interesting to note that infectious diseases and immunology that were on top of the list in Table 6 are falling lower on the list of Table 9. When there is no non-African influence, the co-authorship priorities change. Infectious diseases and immunology appear to be led by foreign researchers.

Table 9: Co-authored research areas without non-African participants 2012–2014

Research Areas	Number of Publications out of 563
Agriculture	56 (9.9%)
Environmental Sciences Ecology	44 (7.8%)
Public Environmental Occupational Health	31(5.5%)
Plant Sciences	30 (5.3%)
Mathematics	25 (4.4%)
Engineering	24 (4.2%)
Physics	24 (4.2%)
Water Resources	24 (4.2%)
Chemistry	22 (3.9%)
Geology	22 (3.9%)
Infectious Diseases	22(3.9%)

The main participants in co-authorship between South Africa–SADC without non-African participants are the University of Cape Town (15.2%); University of Pretoria (15.1%); University of Zimbabwe (13.8%); University of Witwatersrand (12.7%); and University of KwaZulu-Natal (12.4%).

Table 10 shows the number of co-authored publications between South Africa and the various SADC countries during 2012–2014 and 2002–2004. It becomes apparent that co-authorship in water research is almost non-existent. Analysis of the type of publications shows that 78% are articles. The rest are editorial material, conference presentations and others. The countries with some minimal collaboration in water – Zimbabwe and Namibia – are among the most water-constrained countries in the region.

Table 10: South Africa–SADC countries general and water co-authorship 2012–2014 and 2002–2004

	2012–2014		2002–2004	
Country (with South Africa)	**All Documents**	**Water Resources**	**All Documents**	**Water Resources**
Angola	10	0	0	0
Botswana	186	9	50	2
Congo	46	0	1	0
Lesotho	25	0	6	2
Madagascar	47	0	20	0
Malawi	229	5	0	0
Mauritius	42	0	21	0
Mozambique	97	0	51	2
Namibia	221	12	0	0
Seychelles	13	0	5	0
Swaziland	60	0	30	3
Tanzania	265	2	24	1
Zambia	188	0	92	11
Zimbabwe	404	19	15	0

Table 11 shows the collaboration matrix of SADC countries in all research disciplines. The table reveals the countries who tend to collaborate within SADC and their preferences. All countries have higher number of collaborative publications with South Africa than with any other country in the region.

Table 11: SADC collaboration matrix – all publications (2012–2014)

	South Africa	Tanzania	Zimbabwe	Malawi	Zambia	Botswana	Congo	Mozambique	Namibia	Mauritius	Angola	Swaziland	Seychelles	Lesotho
South Africa		267	406	237	188	187	50	97	221	42	11	60	13	26
Tanzania	267		56	54	75	26	9	41	16	3	0	5	3	1
Zimbabwe	406	56		72	65	32	9	9	16	0	0	3	0	0
Malawi	237	54	72		51	20	5	23	15	0	0	3	0	4
Zambia	188	75	65	51		24	12	24	11	1	0	5	0	1
Botswana	187	26	32	20	24		2	8	15	1	1	3	0	1
Congo	50	9	9	5	12	2		2	3	2	1	0	1	0
Mozambique	97	41	9	23	24	8	2		8	1	5	3	1	3
Namibia	221	16	16	15	11	15	3	8		4	4	4	0	3
Mauritius	42	3	0	0	1	1	2	1	4		0	0	1	0
Angola	11	0	0	0	0	1	1	5	4	0		0	0	0
Swaziland	60	5	3	3	5	3	0	3	4	0	0		0	2
Seychelles	13	3	0	0	0	0	1	1	0	1	0	0		0
Lesotho	26	1	0	4	1	1	0	3	3	0	0	2	0	

Table 12 shows the SADC collaboration matrix in water-related research. The matrix reveals that there is minimal if any collaborative research on the topic. Some seed level research exists between South Africa, Zimbabwe and Namibia.

Table 12: Water research collaboration matrix (2012–2014)

	South Africa	Tanzania	Zimbabwe	Malawi	Zambia	Botswana	Congo	Mozambique	Namibia	Mauritius	Angola	Swaziland	Seychelles	Lesotho
South Africa		2	19	5	0	9	0	0	12	0	0	0	0	0
Tanzania	2		0	0	0	0	0	0	0	0	0	0	0	0
Zimbabwe	19	0		3	0	2	0	0	7	0	0	0	0	0
Malawi	5	0	3		0	6	0	0	2	0	0	0	0	0
Zambia	0	0	0	0		0	0	0	0	0	0	0	0	0
Botswana	9	0	2	6	0		0	0	2	0	0	0	0	0
Congo	0	0	0	0	0	0		0	0	0	0	0	0	0
Mozambique	0	0	0	0	0	0	0		0	0	0	0	0	0
Namibia	12	0	7	2	0	2	0	0		0	0	0	0	0
Mauritius	0	0	0	0	0	0	0	0	0		0	0	0	0
Angola	0	0	0	0	0	0	0	0	0	0		0	0	0
Swaziland	0	0	0	0	0	0	0	0	0	0	0		0	0
Seychelles	0	0	0	0	0	0	0	0	0	0	0	0		0
Lesotho	0	0	0	0	0	0	0	0	0	0	0	0	0	

In summary, the main findings of this section are as follows:

- South Africa is the most prolific SADC country in publishing in general, and in water research in particular.
- It is argued that only South Africa has a critical mass of researchers in the water field.
- Comparisons of the absolute number of water-related research and the share of the field in the country's publications lead to the conclusion that the issue is not lack of water research but a lack of research in general.
- Focusing on the collaborative patterns of South Africa, it is identified that South Africa's publication output is 52% collaborative with other countries. Only 6.4% of the co-authored publications had at least one co-author from the SADC region. This figure decreased to 2.4% when publications excluded non-African authors.
- Zimbabwe is the country among the SADC countries who collaborates with South Africa the most (almost 27% of all co-authored publications during the 2012–2014 period). Tanzania and Malawi follow on the list.
- The main funders of research as they appear in the end of the various publications are as follows: NRF appears in 180 publications; Bill and Melinda Foundation follows with 72 publications; NIH with 64 publications; Wellcome Trust with 60 publications; and BMBF, CNRS and Max Plank Society with 32 publications each.
- Infectious diseases and immunology are the most collaborative research fields with international influence. Intra-SADC collaboration (without non-African influence) focuses on agriculture and environmental sciences ecology.
- The main organisations cooperating in the South Africa–SADC publications are the University of Cape Town and the University of Witwatersrand with approximately 19% of the total collaboration each. The University of KwaZulu-Natal and the University of Pretoria follow. The universities of Zimbabwe and Malawi are the top contributors in the South Africa–SADC collaboration from the SADC region.
- The SADC collaboration matrix in water-related research reveals that there is minimal, if any, collaborative research on the topic. Some seed level research exists between South Africa, Zimbabwe and Namibia.

5 SURVEY

A survey was undertaken to identify factors affecting positive or negative research collaboration in the SADC region. A questionnaire was developed (Appendix 3), which was emailed to 83 researchers during August and September 2016. The researchers were identified among those with co-publications with researchers from neighbouring countries, participants of WRC projects, and/or people with relevant expertise. A number of reminders were sent, and a number of telephone conversations took place to improve the return rate. Thirty-four usable questionnaires were received for a return rate of just below 41%. Twenty-seven of the respondents declared that they had collaborated with researchers in other countries.

The questionnaire asked the participants to identify whether a number of factors were facilitating or inhibiting cross-border collaboration. A scale from 1 to 5 was used (1: strongly inhibits; 5: facilitates). Figure 3 to Figure 11 show diagrammatically the responses for each question.

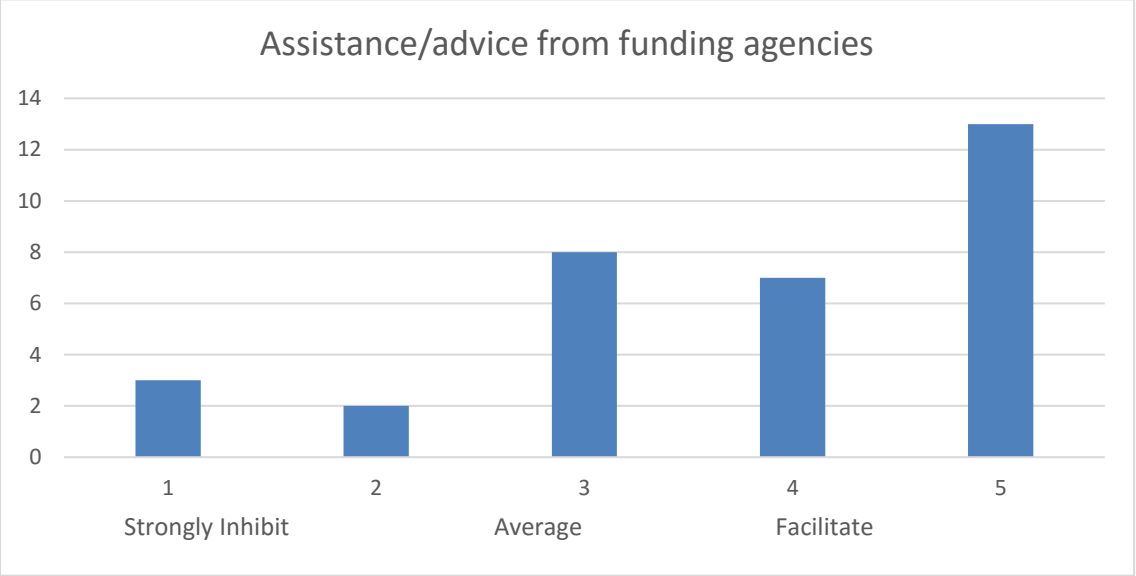

Figure 3: Responses related to assistance/advice from funding agencies

Figure 4: Responses related to assistance/advice from their institution

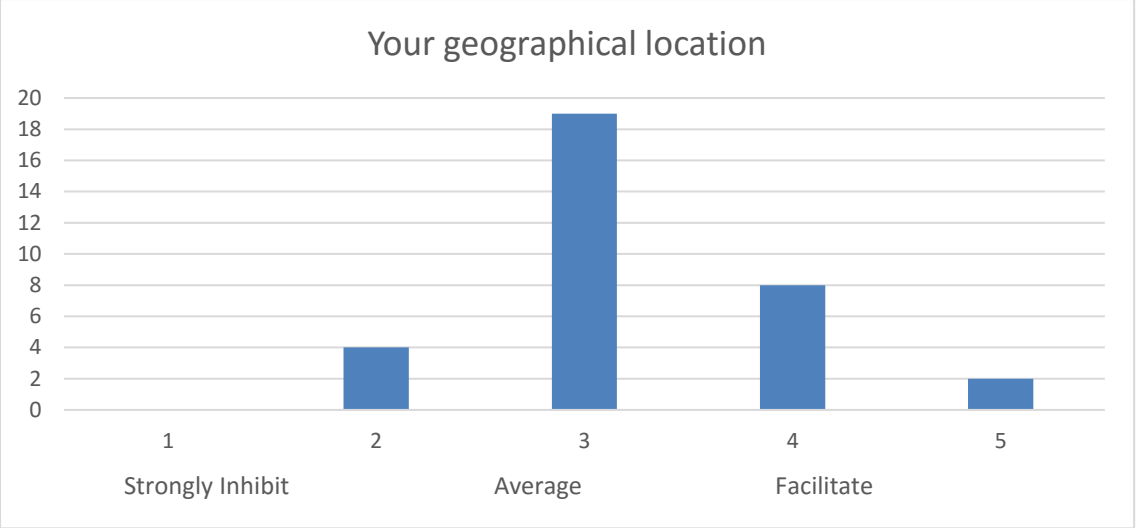

Figure 5: Responses related to geographic location

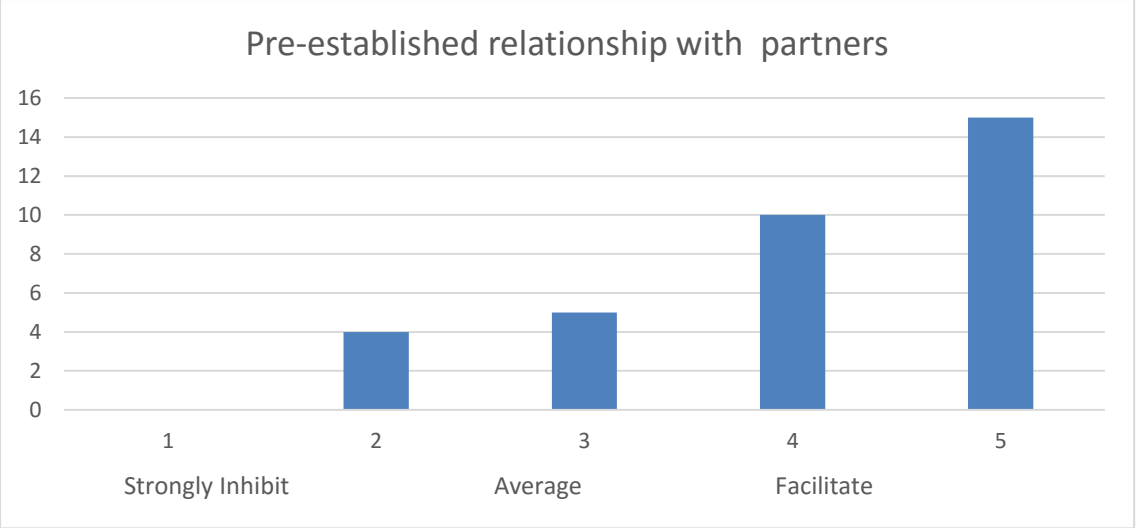

Figure 6: Responses related to pre-established relationship with partners

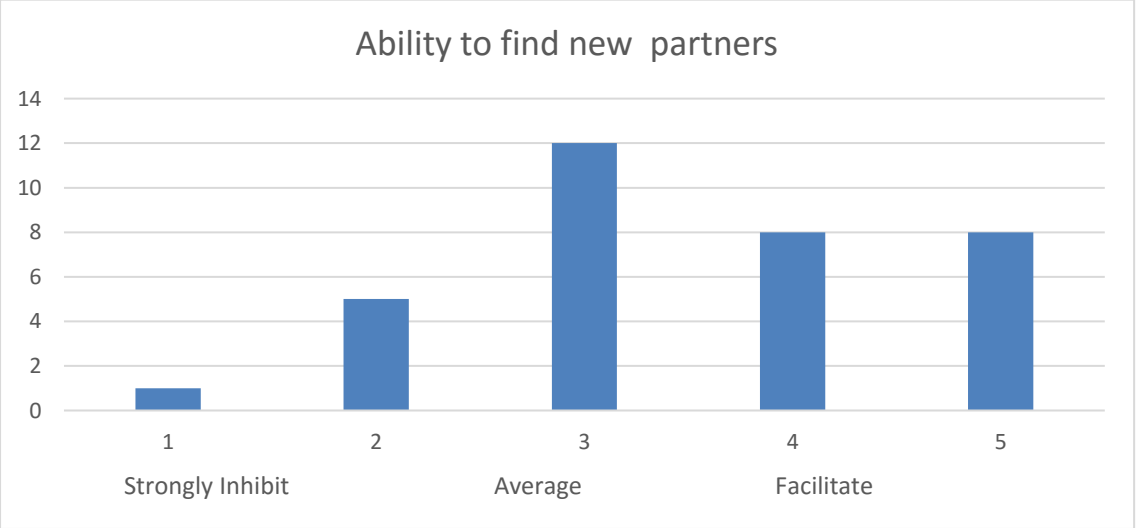

Figure 7: Responses related to ability to find partners

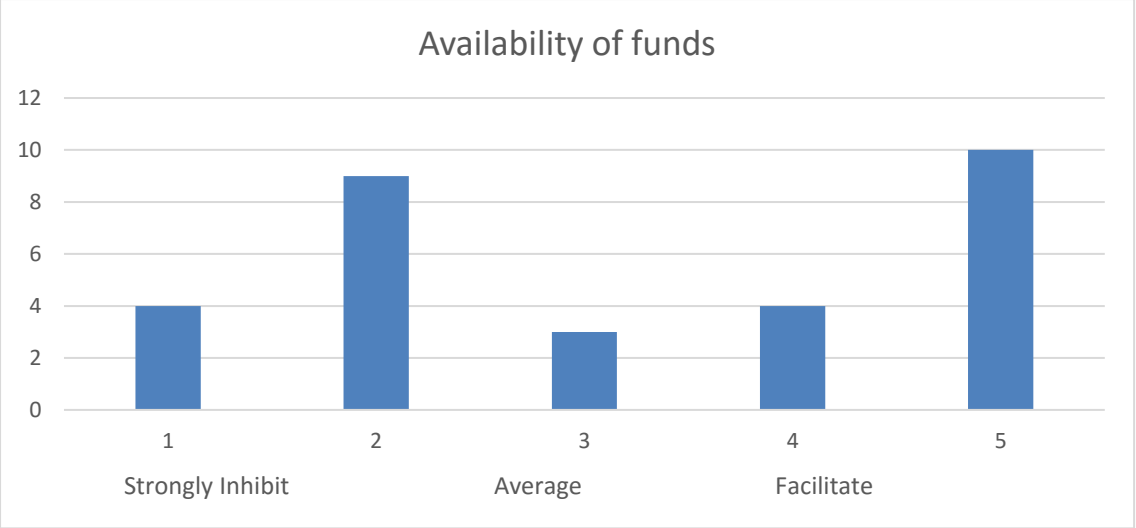

Figure 8: Responses related to the availability of funds

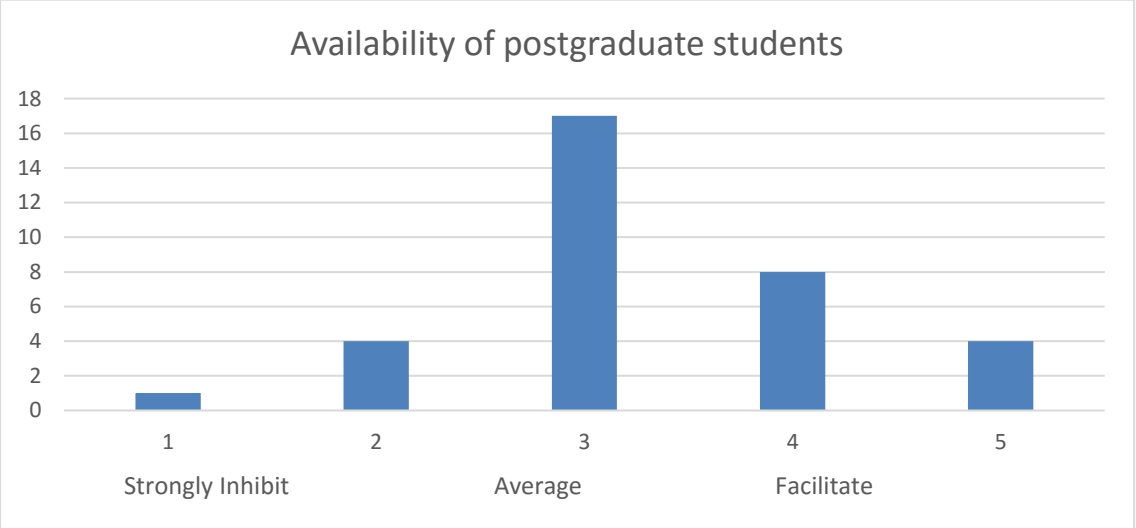

Figure 9: Responses related to availability of postgraduate students

Figure 10: Responses related to availability/expertise of partner

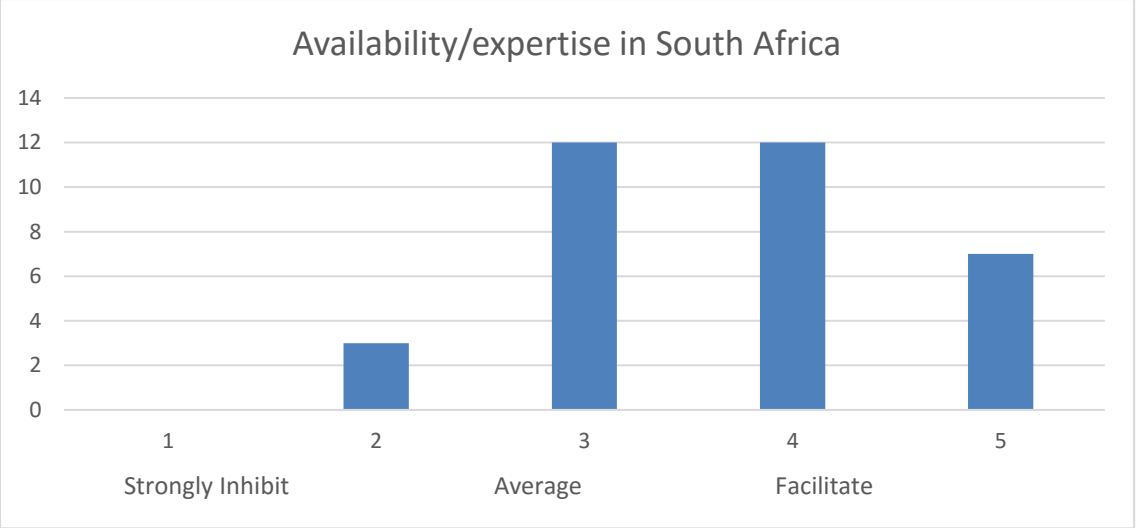

Figure 11: Responses related to availability/expertise in South Africa

Figure 12 provides a synoptic picture of the responses. Green indicates middle responses (3 from 1 to 5). Availability of funds is identified as attracting most of the votes as inhibiting collaboration. Seventeen respondents said that funds are above average critical for collaboration. A pre-established relationship with partners was identified as a facilitating factor for collaboration. Thirty participants mentioned that pre-established relationships were average or were facilitating collaboration. Advice of funding bodies or own institutions was also facilitating collaboration.

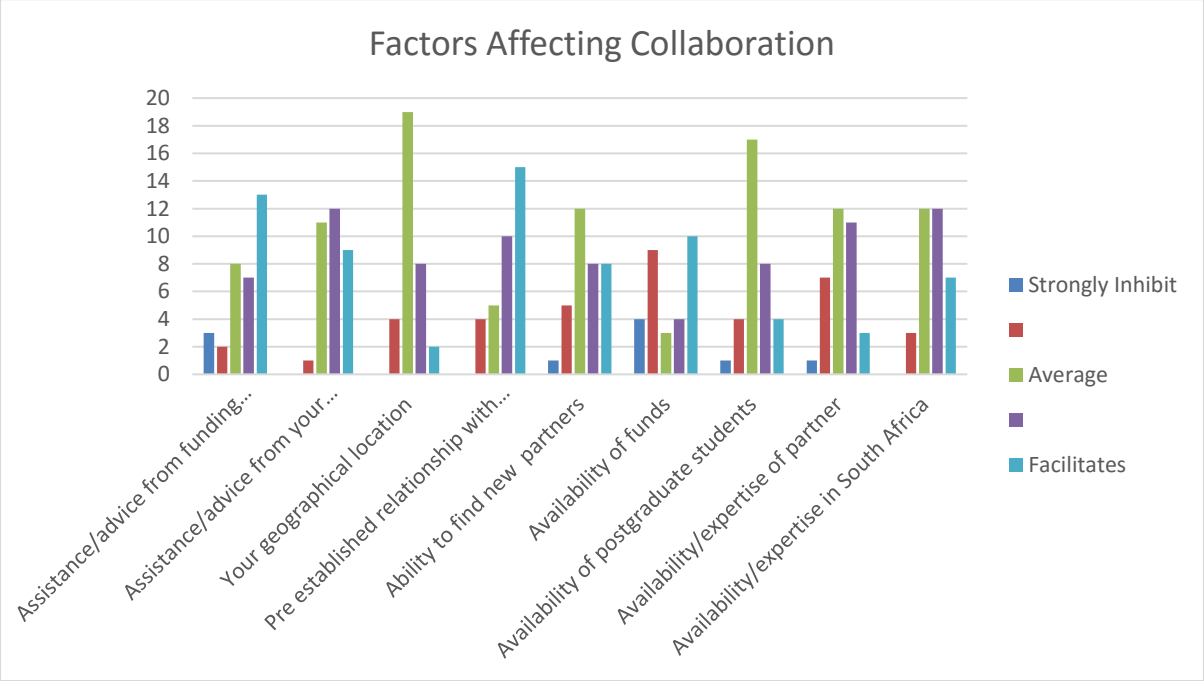

Figure 12: Summary of responses of factors affecting collaboration

The respondents were asked to suggest other factors that may facilitate or inhibit collaboration. Some of the suggestions were:

- Prioritisation of the issue at government level.
- Reliable regional database of water resources.
- Academia to drive the collaborative effort.
- Availability of suitable postgraduate student from the collaborator's country.

The hindering factors were identified as:

- The lack of infrastructure and credible partners in Africa.
- Lack of available hydroclimatic data.
- South Africa's image as the guiding providing country in the region.

Respondents were asked if they consider that research collaboration in the field of water is desirable. All respondents declared that they thought that research collaboration in the field is necessary. Examples include:

> "*Water research in the SADC region is very important for the development of the region. Moreover, we need expertise/manpower who have to take the lead for the protection of water resource and to counteract the pollution*"

> "*The SADC region face enormous challenges in terms of climate change, food security an integrated water resource management (to name but a few). Scientific research can contribute in addressing these challenges. Since 1980, 82% of water resource publications in peer-reviewed journals were published by South African research institutions (Web of Science). This can be attributed to various factors, which include the sheer number of universities and research institutions in South Africa (in comparison to other SADC countries) and also access to financial resources provided by institutions such as the NRF and WRC. South African universities and research institutions also have better physical infrastructure if compare to many SADC/African countries.*
>
> *South African research institutions thus have a lot to offer, compared with other SADC universities and research institutions, which can be tapped through research collaborations.*"

> *"Most definitely! I presented a paper at the PANC 2016 conference in Nairobi, Kenya in December 2016 and it is clear that irrespective of our country of origin, we all experience very similar water availability and quality issues"*

> *"Unfortunately, most of my collaboration has been with partners in North Africa. It is imperative as a region that supporting mechanisms from funding agencies should be further prioritised."*

> *"Yes – necessary to have research on the following as they affect all SADC countries:*
>
> - *Common policies for scarce resources and/or unevenly distributed resources.*
> - *Food security is dependent on water resources.*
> - *Changing environment affects food security.*
> - *Water management is of paramount importance".*

> *"It is essential, but something substantial has to be done. 'Water' has been identified as a regional priority over many decades; the first time I was involved was in 1981/82 while serving on the HSRC's national advisory priorities committee".*

Finally, the questionnaire posed the question “How South Africa–SADC collaboration in the field of water research can be strengthened”. Some of the responses include the following:

> *“Strengthen coordination of water research activities – very fragmented.”*

> *“Link water research to broader societal issues e.g. health.”*

> *“Establish a water research call for SADC countries with invitation to European countries for participation with their own funds”*

> *“Arrange networking events with the aim to create a platform for joint collaboration for SADC countries with invitation to European countries to participate.”*

> *“Create a theme-based database/platform where research projects are promoted for participation by SADC and European countries – in addition to the WRC website but to include all research in SA/SADC if possible.”*

> *“WRC to establish a satellite research station in a SADC country.”*

> *“Ensure that research is relevant to current challenges.”*

> *“There is need for dedicated funding research for the management and utilisation of shared water resources in the region”*

> *“The WRC should decide whether this is indeed a priority funding area. Proposals from our group in this regard have been unsuccessful for the past few years so we will no longer pursue this research area via the WRC”*

> *“Identify water issues in SADC countries and establish bilateral or multilateral research partnership programmes. There are a number of research chairs on water issues that are supported through the NRF and they might be a good springboard from which such partnerships could start.*
>
> *A multilateral research chair, funded commonly by the WRC and NRF on a specific water issue might also be a good start. The exchange of researchers, postdoctoral fellows and doctoral students could be a basis for future water research in SADC countries as well.”*

Most of the suggestions revolved around prioritising water research at national levels and providing financial and informational support.

6 FINDINGS AND RECOMMENDATIONS

The objective of this report is to contribute to the issues of science diplomacy related to water in the SADC region. Science diplomacy refers to the role of science in three dimensions of policy (The Royal Society 2010):

- Science in diplomacy: informing foreign policy objectives with scientific advice.
- Diplomacy for science: facilitating international science cooperation.
- Science for diplomacy: using science cooperation to improve international relations between countries.

It is argued that all three dimensions depend on scientific collaboration among the researchers of the collaborating countries.

The character and uses of water resources (ranging from drinking to navigational uses, and from irrigation to electricity production) elevate the importance of science diplomacy in the domain of water. The relevant literature identifies that active water cooperation between countries not only improves development in the participants, but it also reduces the risk of conflict and war in general.

The literature review identifies that improved water management (e.g., pricing, allocations, and virtual water trade) and investments in water-related sectors (e.g., agriculture, power, and water treatment) will afford the best solutions for water problems.

Furthermore, the WFD of the EU is considered good practice. Under the WFD, all river catchments (rivers, streams, lakes and the land that drains into them) are assigned to administrative RBDs by member states. Member states are required to produce RBMPs for all RBDs in the EU.

In the SADC regions, certain countries share certain characteristics related to water and shared resources. The four most water-constrained countries who are on the 'wrong side' of the global average isohyet of 860 mm/yr^{-1} – Botswana, Namibia, South Africa and Zimbabwe – are also the countries who share the largest number of transboundary aquifers – Botswana (eight), Namibia (six), South Africa (nine) and Zimbabwe (four).

A number of protocols and regimes govern the basins. Researchers investigating the governance of the various basins suggest that water resource management in transboundary river systems is not a major driver of conflict in the SADC region.

The DST has several bilateral agreements with other SADC countries. A number of them postulate collaboration in the field of water as well. However, it is identified that currently there are not instruments supporting scientific collaboration among the local and neighbouring researchers in the field of water.

A scientometric analysis identifies the following:

- South Africa is the most prolific SADC country in publishing in general and in water research in particular.
- It is argued that only South Africa has a critical mass of researchers in the water field.
- Comparisons of the absolute number of water-related research and of the share of water publications in the country's publications lead to the conclusion that the issue is not lack of water research but a lack of research in general.
- Focusing on the collaborative patterns of South Africa, it is identified that South Africa's publication output is 52% collaborative with other countries. Only 6.4% of the co-authored publications had at least one co-author from the SADC region. This figure decreased to 2.4% when publications exclude non-African authors.
- Zimbabwe is the country among the SADC countries who collaborates with South Africa the most (almost 27% of all co-authored publications during the 2012–2014 period). Tanzania and Malawi follow on the list.

- The main funders of research as they appear in the acknowledgements of the various publications are: NRF appears in 180 publications; Bill and Melinda Foundation follows with 72 publications; NIH with 64 publications; Wellcome Trust with 60 publications; and BMBF, CNRS and Max Plank Society with 32 publications each.
- Infectious diseases and immunology are the most collaborative research fields with international influence. Intra-SADC collaboration (without non-African influence) focuses on agriculture and environmental sciences ecology.
- The main organisations cooperating in the South Africa–SADC publications are the University of Cape Town and the University of Witwatersrand with approximately 19% of the total collaboration each. The University of KwaZulu-Natal and the University of Pretoria follow. The universities of Zimbabwe and Malawi are the top contributors in the South Africa–SADC collaboration from the SADC region.
- The SADC collaboration matrix in water-related research reveals that there is minimal, if any, collaborative research on the topic. Some seed level research exists between South Africa, Zimbabwe and Namibia.

A survey among the South African researchers collaborating on water issues with colleagues abroad identified that researchers believe that such collaboration is useful in the field of water. Furthermore, they suggest that availability of funding and information resources can improve the state of collaboration in the field in the region.

The above leads to following recommendations:

- The WRC, DST, DWS and Department of Foreign Affairs in conjunction with the SADC secretariat and the relevant countries should aim to create a Common Water Research Area in the SADC region. The effort could aim to imitate the European Research Area and it could be the first step towards an SADC Research Area. WRC has a better chance to succeed in initiating such an effort because of the subject matter, the size of effort and the option of by-passing political challenges.
- The WRC should consider the identification of international and national resources to establish water-related research capacity in the neighbouring countries.
- The WRC has the opportunity to provide leadership in the SADC region the same way that it provides leadership in South Africa. Institutionalisation should be considered within WRC.
- The DST and NRF should consider enlarging the established and planned collaboration instruments to include seed funding for the establishment of new partnerships; support for bursaries; postgraduate grants and similar.
- The WRC should consider developing an information database including the names and particulars of all researchers with publications/expertise in the field of water in the SADC countries. The database should aim to facilitate the identification of researchers with particular water expertise in the region. The database should be publicly available and be updated regularly.

REFERENCES

Altchenko Y, and Villholth GK. (2013). Transboundary aquifer mapping and management in Africa: A harmonised approach. *Hydrogeology Journal* **21(7):** 1497–1517.

American Association for the Advancement of Science Centre for Science Diplomacy (AAAS). (2009). *American Association for the Advancement of Science Centre for Science Diplomacy: Inaugural Year in Review.* American Association for the Advancement of Science: Washington, DC. Available online: www.diplomacy.aaas.org/fi les/ CFD_YIR_Web.pdf.

Beaver D deB, and Rosen, R. (1978). Studies in scientific collaboration: Part I. Professional origins of scientific co-authorship. *Scientometrics* **1(1):** 65–84.

Boshoff N. (2010). South–south research collaboration of countries in the Southern African Development Community (SADC). *Scientometrics* **84(2):** 481–503.

Breen C, Crafford J, Mitchell S, and Roux D. (2013). *The review, re-conceptualization and re-design of the shared rivers initiative programme.* Water Research Commission Research Report No. KV 314/13, Pretoria.

Chang H-W, and Huang M-H. (2013). Prominent institutions in international collaboration network in astronomy and astrophysics. *Scientometrics* **97:** 443–460.

Flink T, and Schreiterer U. (2010). Science diplomacy at the intersection of S&T policies and foreign affairs: Towards a typology of national approaches. *Science and Public Policy* **37(9):** 665–677.

Frankena F. (1988). The emergent social role and political impact of the voluntary technical expert. *Environmental Impact Assessment Review* **8(1):** 73–82.

Govtrack.US. (2010). *Text of the Global Science Programme for Security, Competitiveness and Diplomacy Act of 2010.* Available online: https://www.govtrack.us/congress/bills/111/hr4801/text [Accessed March 2016].

Holzinger K. (2000). *Optimale Regulierungseinheiten f.ur Europa. Flexible Kooperation territorialer und funktionaler Jurisdiktionen* as quoted in Moss (2004) Unpublished Paper Presented to 21st Scientific Congress of the DVPW, 1–5 October in Halle.

Intelligence Community Assessment. (2012). *Global Water Security*. ICA 2012-08; 2 February 2012.

Jacobs IM, and Nienaber S. (2011). *Incentivising young social science perspectives in the SADC water sector: Building a forum for young scholars in transboundary water governance*. Water Research Commission Research Report No. TT 487/11.

Japanese Council for Science and Technology Policy. (2008). *Toward the reinforcement of science and technology diplomacy. Cabinet Office: Tokyo*. Available online: www8.cao.go.jp/cstp/english/doc/ s_and_t_diplomacy/20080519_tow_the_reinforcement_of.pdf.

Jasanoff S. (1990). *The Fifth Branch: Science Advisers as Policymakers*. Cambridge, MA and London: Harvard University Press.

Lee DH, Seo IW, Choe HC, and Kim HD. (2012). Collaboration, network patterns and research performance: The case of Korean public research institutions. *Scientometrics* **91:** 925–942.

Moss T. (2004). The governance of land use in river basins: Prospects for overcoming problems of institutional interplay with the EU Water Framework Directive. *Land Use Policy* **21:** 85–94.

Mostert E. (2003). *Conflict and cooperation in the management of international freshwater resources: A global review*. UNESCO, IHP, WWAP. Technical documents in Hydrology no. 19.

Narin F, Stevens K, and Whitlow E. (1991). Scientific cooperation in Europe and the citation of multinationally authored papers*. Scientometrics* **21:** 313–323.

Nye SJ. (2004). *Soft Power: The Means to Success in World Politics*. New York, NY: Public Affairs.

Onyancha OB, and Maluleka JR. (2011). Knowledge production through collaborative research in sub-Saharan Africa: How much do countries contribute to each other's knowledge output and citation impact? *Scientometrics* **87(2):** 315–336.

Pacific Institute. (2016). *Water conflict chronology*. Available online: http://worldwater.org/water-conflict/.

Parliamentary Office of Science and Technology (POST). (2008). *River Basin Management Plans Parliamentary Office of Science and Technology*. Number 320. London SW1P 3JA.

Pouris A. (2010). A scientometric analysis of SADC countries: Science in the tip of Africa. *Scientometrics* **85(1):** 145–154.

Pouris A. (2012). Scientometric research in South Africa and successful policy instruments. *Scientometrics* **91:** 317–325.

Pouris A, and Ho Y-S. (2014). Research emphasis and collaboration in Africa. *Scientometrics* **98:** 2169–2184.

Puri S, and Aureli A. (2005). Transboundary aquifers: A global programme to assess, evaluate, and develop policy. *Groundwater* **43:** 661–668.

Schreiner B, Mtsweni A, and Pegram G. (2011). *An institutional framework for stakeholder participation in transboundary basins*. Water Research Commission Research Report No. 1758-1-10.

Schubert, T, and Sooryamoorthy R. (2010). Can the centre-periphery model explain patterns of international scientific collaboration among threshold and industrialised countries? The case of South Africa and Germany. *Scientometrics* **83(1):** 181–203.

Sooryamoorthy R. (2009). Collaboration and publication: How collaborative are scientists in South Africa? *Scientometrics* **80(2)**, 419–439.

Southern African Development Community (SADC). (1995). *Protocol on shared watercourse systems in the Southern African Development Community (SADC) region*. SADC Secretariat, 1995 Gaborone.

Strategic Foresight Group. (2013). *Water cooperation for a secure world*. Mumbai, India.

The Royal Society. (2010). *New frontiers in science diplomacy.* RS Policy document 01/10; London SW1Y 5AG.

Turekian CV, and Neureiter PN. (2012). Science and diplomacy: Thee past as prologue*. Science and Diplomacy*. Available online: http://www.sciencediplomacy.org/editorial/2012/science-and-diplomacy.

Turton A. (2010). *New thinking on the governance water and river basins of Africa: Lessons from the SADC region*. Johannesburg: South African Institute of International Affairs.

Turton AR, Ashton PJ, and Jacobs I. (2008). *The management of shared water resources in southern Africa*. CSIR report no. CSIR/NRE/WR/ER/2008/0400/C.

United Nations Conference on Trade and Development (UNCTAD). (2003). *Science and technology diplomacy: Concepts and elements of a work programme*. United Nations Conference on Trade and Development: Geneva. Available online: www.unctad. org/en/docs//itetebmisc5_en.pdf.

Wagner CS, Staheli L, Silberglitt R, Wong A, and Kadtke J. (2002). *Linking effectively: Learning lessons from successful collaboration in science and technology*, Rand, Santa Monica, CA.

Wagner SC, Staheli L, Kadtke J, Silberglitt R, and Wong A. (2002a). *Linking effectively: International cooperation in science and technology*. Rand report.

White House. (2009). *Remarks by the President at Cairo University: 6-04-09.* Available online: https://www.whitehouse.gov/the-press-office/remarks-president-cairo-university-6-04-09.

Yeung YY, Liu TCY, and Ng PH. (2005). A social network analysis of research collaboration in physics education*. American Journal of Physics* **73(2):** 145–150.

Zdravkovic M, Chiwona-Karltun L, and Zink E. (2016). Experiences and perceptions of south–south and north–south scientific collaboration of mathematicians, physicists and chemists from five southern African universities*. Scientometrics* **108:** 717–743.

APPENDIX 1: AFRICA COOPERATION BILATERAL PROGRAMME

CALL FOR JOINT PROPOSALS – 2016
Research to commence in 2017
Egypt, Kenya, Namibia, Uganda
CLOSING DATE: 16 MAY 2016

The National Research Foundation (NRF) invites joint project proposals in support of its Africa bilateral initiatives in promoting and supporting continental and regional scientific collaboration in order to contribute to the socio-economic and sustainable growth on the African continent. For this round of applications, one call for Africa bilaterals is published for applications for joint research proposals with respectively Egypt, Kenya, Namibia and Uganda.

Working closely with the Department of Science and Technology (DST), the Africa Cooperation unit of International Relations and Cooperation (IRC) assumes a proactive responsibility to facilitate and enhance international scientific collaboration between individual scientists, higher education institutions, research bodies and scientific and professional associations (unions) in South Africa and abroad.

Aims of the bilateral programme

- To collaborate on research projects selected within joint calls for proposals.
- To contribute to scientific advancement in South Africa and its African partner country through the funding of joint research activities in specified research fields.
- To provide an opportunity for young researchers in the two countries to engage.
- To support the advancement of research.
- To contribute meaningfully to research capacity development.

Eligibility

An application must designate **two principal investigators**, one in South Africa and the one in the relevant partner country **both in possession of doctoral degrees**, who will bear the main responsibility for the project, including its technical and administrative coordination, and scientific and financial reporting. The South African applicant must be employed at a recognised higher education or research institution such as a university, university of technology or science council. Commercial institutions and private education institutions are not eligible to apply under this programme.

Application process

The joint research project proposals shall be submitted to the relevant competent authorities in the respective countries for evaluation as follows:

- NRF, South Africa.
- Science and Technology Development Fund (STDF), Egypt.
- National Commission for Science, Technology & Innovation (NACOSTI), Kenya.
- National Commission on Research, Science and Technology (NCRST), Namibia.
- Uganda National Council for Science and Technology (UNCST), Uganda.

Proposals must be received in both South Africa and the partner country. Proposals which have only been received in either, but not both countries, will not be considered for funding.

A multi-institutional/consortia approach will be preferred. Participation of an industry partner on both sides will be encouraged. However, industry is expected to meet their participation costs in the project.

In South Africa

South African applicants can apply by following the steps below:

- Applications must be submitted electronically to the NRF on the NRF Online Submission System at https://nrfsubmission.nrf.ac.za/.
- Register/Log in using your ID number and password.
- Go to “My Applications” and select “Create Application”.
- Select the call for which you are applying for, which will be **EITHER:**
    - **South Africa–Egypt Bilateral Call 2016**
    - **South Africa–Kenya Bilateral Call 2016**
    - **South Africa–Namibia Bilateral Call 2016**
    - **South Africa–Uganda Bilateral Call 2016**
- Complete all compulsory and the CV sections in full. Please attach the required documents in PDF format.
- Remember to submit your application on completion.
- Complete applications will go to the host institutions for verification before being forwarded to the NRF for further processing.
- Incomplete applications will not be considered.
- Applications that do not meet the eligibility criteria will not be considered.
- Please contact your research office or Designated Authority if you have any queries.

The application must consist of:

- The NRF electronic application form;
- A signed statement from the South African AND the partner principal researcher/project manager and their respective responsible institutions confirming that the proposal is submitted jointly with the approval of the institution;
- The curriculum vitae of the collaborator (CV’s should be limited to a maximum of four pages and focus on the most important research projects and publications);
- A list of team members on the partner country side; and
- Budget of the partner in their currency.

Please note:

Applications submitted outside the NRF Online Submission System will not be accepted. **No hard copies will be accepted and will automatically be disqualified by the NRF.** Only applications endorsed by the research office or its equivalent at higher education or research institutions will be accepted.

Funding modalities and areas of cooperation

Joint research proposals can be submitted in the following areas of cooperation prioritised by the particular country, for the specific period/ duration as specified, and to a maximum of the respective amount:

	Egypt (Appendix I)	Namibia (Appendix II)	Kenya	Uganda
Thematic areas	• Space Sciences & Technology. • Energy. • Water Resource Management. • Food and Agriculture. • ICT.	• Biosciences. • ICT. • IKS. • Energy and Environmental Sciences. • Social Sciences.	• Agricultural sciences. • Biological Sciences. • Health. • Environmental sciences. • ICT.	• Renewable energy. • Biotechnology (health and agriculture). • ICT (education).
Duration of projects	3 Years	3 Years	3 Years	2 Years
Maximum funding levels	• NRF: R500 000 for a maximum of 3 years, paid in annual instalments as would have been indicated on the application. • STDF: 240 000 EGP over 3 years; 80 000 EGP per project per year.	• NRF: R600 000 for a maximum of 3 years, to be paid in annual instalments of R200 000 per year. • NCRST: N$600 000 for a maximum of 3 years, to be paid in annual instalments of N$ 200 000 per year.	• NRF: R400 000 for a maximum of 3 years, paid in annual instalments as would have been indicated on the application. • NACOSTI: Ksh. 3 000 000 over three years to be paid in annual instalments subject to satisfactory progress report.	• NRF & UNCST: The total amount applied for jointly should not exceed R500 000 (UGX 150 000 000) available for a maximum of two years, to be paid in annual instalments.
No. of projects to be funded	10	15	10	6
Who may apply in the partner country	The PI and other investigators in Egypt should be scientists/ faculty members working in a regular capacity in Egyptian universities, academic institutes and National Research and Development Centres/Laboratories/ Institutes.	Lead applicants must be scientists/ faculty members from qualified institutions including public universities and research institutions and science councils	The lead Kenyan applicants should be scientists/ faculty members from qualified institutions including public universities and research institutions, science councils, and licensed private universities or private research institutions.	This call is open to researchers residing in Uganda from qualified institutions including public universities and research institutions, science councils, and licensed private universities or private research institutions.

	Egypt (Appendix I)	Namibia (Appendix II)	Kenya	Uganda
How to apply in the partner country	These applications have to be submitted jointly to the NRF-STDF platform established using the NRF Online Submission System at https://nrfsubmission.nrf.ac.za/. This implies the complete merging of both partners' proposals in this platform. The Egyptian partners will be able to access the electronic application form by using the password of their respective South African partners, and therefore both PIs should be collectively responsible to manage their joint applications.	• Go to www.ncrst.na • Register via the online registration portal for the 4th Joint Call. • Upon registration, application documents will become available for download. • Complete all compulsory sections applicable to you. • Remember to submit your application on completion. Submissions are to be made to jointcall@ncrst.na • Complete applications will go to the host institutions for verification before being forwarded to the NCRST for further processing.	• Application forms for proposal submission may be obtained from the NACOSTI website (www.nacosti.go.ke). • Electronic copies of the complete application form together with the signature page must be emailed to (research@nacosti.go.ke). • Signatures may either be signed electronically or scanned.	• Application forms for proposal submission may be obtained from the UNCST website (www.uncst.go.ug). • Signatures may either be signed electronically or scanned.

Joint activities to be covered

The purpose of these programmes is to support the research projects and mobility of researchers, scientists, and postgraduate students between the two countries. Funding will be made available for the following joint research activities undertaken as part of the joint research project:

- **Support for research expenses:** Expenditure by project team in their country would be borne by the respective country. A maximum of 15% of the budget may be allowed for small equipment.
- **Support for the exchange visit component:** In the case of meetings, research visits and exchanges of scientists, personnel and experts, as well as reciprocal visits undertaken as part of joint research projects and the attendance of seminars, symposia and other meetings funded under this agreement, **the sending side will be responsible for financing international travel, visas, and medical insurance, while the receiving party will be responsible for financing the accommodation and subsistence of their international partners**.

Local travel and fees relating to the organisation of events (venue, catering, audio-visual equipment etc.) will be the financial responsibility of the host investigator which is to be paid from his/her allocation of the joint funding.

Eligible costs

The following will **NOT** be funded from the NRF grant:

- Consultant's fees.
- Educational expenses (scholarships and/or bursaries, etc.)
- Large equipment.
- Project management fees.
- Salaries and temporary staff fees.

All other expenses, including operational running costs and research materials, may be financed from the allocation accorded in terms of this call. Should the allocated funds allow – researchers may also make use of these for joint publication costs. All the approved projects will receive funding support from the two parties in terms of the cost of activities mentioned above. Apart from the financial support from the two parties, institutions and universities in both countries are encouraged to solicit other funding resources.

Evaluation criteria for all countries

Following the closing date indicated below, applications will be submitted to both a postal and a panel review. The panel will include recognised experts in the various fields of research represented by the proposals received. The experts will evaluate each proposal based on the following criteria:

- Relevance to the call, added value expected from the bilateral research collaboration.
- Scientific quality and innovativeness of the joint research plan.
- Feasibility of the joint research plan.
- Competence and expertise of the principal investigators and scientists/research teams concerned.
- Possible impact of the research:
    - Industrial development.
    - Technology capacity building.
    - Science and technology human resources development.
    - Possible commercialisation of research results.
    - Social challenges.
- Potential for promoting equity and redress/capacity building.
- Student involvement.

Particular emphasis is to be placed on the training of students and young researchers achieved through research and the transfer of knowledge and know-how aimed at socio-economic community development. The integration of young researchers and students, and the exchange of postdoctoral researchers are encouraged, as is the involvement of students and researchers from previously disadvantaged communities. In terms of human capital development, South African applications from previously disadvantaged researchers are encouraged, as is the involvement of historically disadvantaged higher education institutions.

Kenya and Namibia

Following local evaluation, a shortlist of projects to be funded will be constituted through consultations between the NRF and NACOSTI in Kenya and NCRST in Namibia based on the results of the evaluations done in both countries.

Egypt and Uganda

Applications will be assessed independently by external evaluators in both countries. The results of the external evaluators will be submitted to the respective implementing agencies. These results will be assessed by the NRF-STDF (Egypt) and the NRF–UNCST (Uganda) Joint Panel Committee (JPC) who, together with the secretariat, will prepare a ranking list for approval by the Joint Technical Committee (JTC). The JPC will be comprised of an equal number of local experts, appointed from both countries in the various fields of research represented by the proposals received. Following JPC evaluation, a list of project rankings will be constituted and submitted to the JTC which is the highest decision-making body in the programme and has the final decision on which projects will be funded.

Please note that, although the funding agencies undertake to execute the evaluation and selection process as quickly as possible so as to notify applicants of the results as soon as possible, the nature of the bilateral process requires the alignment of the commencement of each phase of the process with the partnering country, whose schedules may differ significantly. As such applicants are urged not to expect notification by a certain date, nor to make concrete logistical arrangements before having been thus notified. **The call process is highly competitive; therefore, submission of an application does not guarantee funding. The availability of funds and the evaluation of applications from both countries should be positive for them to be considered for funding.**

Projects follow-up and reporting

- For **Egypt** and **Kenya**, technical progress reports will be submitted in English every year where they will be reviewed by NRF and partner agency experts to assess whether the various project tasks are executed in conformity with the planned activities originally outlined in the Gantt chart (timeline) in the submitted application. Financial reports may be submitted more frequently.
- For **Uganda** and **Namibia** Technical Monitoring & Evaluation of progress will be undertaken jointly every six months.
- A final joint scientific and financial report will be submitted in English to the two agencies by both the South African and the project leader in the partner country no more than 3 months after the end of the project.
- The reports will mention the outputs of the projects compared with the objectives and aims targeted in the submission.
- The joint publications will mention the support from the two funding agencies.

Intellectual property

The researchers of each country, particularly the leaders, must take adequate steps to ensure protection and sharing of the intellectual property that could result from the joint projects.

When is the closing date for applications?

Applications must be submitted by **16 May 2016** (for Namibia, the deadline is **31 May 2016**). Applications received after this date will not be considered for funding. Please note that neither the NRF nor the partner agencies will be held responsible for applications that were not received. Researchers are also advised to ensure that their research partner's applications are submitted and have also been received in the partner country.

Where can I obtain more information?

<table>
<tr><th colspan="2">NRF</th></tr>
<tr><td>For programme related queries:
Puleng Tshitlho
Professional Officer: International Relations and Cooperation (IRC)
National Research Foundation
Tel: +27 (0) 12 481 4061
Email: puleng.tshitlho@nrf.ac.za</td><td>For grant and technical related queries:
Jan Phalane
Liaison Officer: Grants Management and Systems Administration (GMSA)
National Research Foundation
Tel: +27 (0) 12 481 4157
Email: jan.phalane@nrf.ac.za</td></tr>
<tr><th>Egypt</th><th>Kenya</th></tr>
<tr><td>Ms Ghada Ghaleb
Project Admin Officer
Science and Technology Development Fund
101 Kasr Al Aini St., Cairo, Egypt
Tel: +202 279 24519
Email: ghada.ghaleb@stdf.org.eg
Website: www.stdf.org.eg</td><td>The Director General
National Commission for Science, Technology and Innovation P.O. Box 30623-00100
NAIROBI
Website: www.nacosti.go.ke
Email: dg@nacosti.go.ke</td></tr>
<tr><th>Namibia</th><th>Uganda</th></tr>
<tr><td>For programme related queries:
Luiza Shekupe
Senior Programme Officer
National Commission on Research Science and Technology
Tel: +264 61 431 7028
Email: jointcall@ncrst.na
For grant and technical related queries:
Alushe Nditya
Manager: Resource Mobilisation & Grant Management
Tel: +264 61 431 7028
Email: jointcall@ncrst.na</td><td>For programme related queries:
Edward Tujunirwe
Head, International Collaborations
Uganda National Council for Science and Technology.
Tel: +256 414 705500/10
Email: t.edward@uncst.go.ug
For grant and technical related queries:
Mr. Ronald Jjagwe
Head, Grants Management
Uganda National Council for Science and Technology
Tel: +256 414 7055000
Email: info@uncst.go.ug or r.jaggwe@uncst.go.ug
Plot 6 Kimera Road, Ntinda, Kampala
Website: www.uncst.go.ug</td></tr>
</table>

Egypt	
	The Republic of South Africa and the Arab Republic of Egypt signed an Agreement for cooperation in science and technology on 26 August 1997. The two countries agreed to jointly support researchers from public universities and public research institutes on an equal and mutually beneficial basis in an effort to enhance scientific and technological and innovation cooperation between the two countries. The cooperation was further strengthened by signing of a Memorandum of Understanding (MoU) regarding cooperation in Science, Technology and Innovation between the National Research Foundation (NRF) of South Africa and the Science & Technology Development Fund (STDF) of Egypt in April 2015.
Kenya	
	The Government of Kenya and the Republic of South Africa signed an Agreement for cooperation in science and technology in August 2004. The two countries have decided to jointly support researchers from public universities and public research institutes on an equal and mutually beneficial basis in an effort to enhance scientific and technological cooperation.
Namibia	
	In March 2005 an agreement on collaboration in Science and Technology was signed between the governments of South Africa and Namibia. This was followed by a Programme of Cooperation (PoC) aimed at implementation of the agreement. The PoC sought to facilitate scientific and technological cooperation between the two countries by supporting researchers from universities, universities of technology, science councils and public research institutes on an equal and mutually beneficial basis. The two countries have also agreed to a Plan of Action (POA) for operationalising full implementation of the Agreement. The parties intend to support research and development activities and other forms of scientific and technical cooperation between South African and Namibian universities and research institutions. The cooperative programmes, projects, and research and development activities will be aimed at the implementation of joint research projects, human capital development, and student and staff exchanges.
Uganda	
	As part of a bilateral agenda to promote Science, Technology and Innovation (STI) and integrate them into their respective national development, Uganda and South Africa signed an agreement for Scientific and Technological Cooperation in April 2009. This agreement allows both Governments to work together to advance science, technology and innovation on the basis of equality and mutual advantage. The two countries have also agreed to a Plan of Action (POA) for operationalising full implementation of the Agreement. The parties intend to support research and development activities and other forms of scientific and technical cooperation between South African and Ugandan universities and research institutions. The cooperative programmes, projects, and research and development activities will be aimed at the implementation of joint research projects, human capital development, and student and staff exchanges.

Egypt

Space Sciences and Technology

- Astronomy
- Remote sensing
- Satellites

Energy Research

- Clean coal burning
- Common areas in natural gas and shale gas
- New trends in renewable energy (e.g. tower technology, improving and localization of inverters for PV, exploring innovations to support manufactures of small wind turbines (1 MW), integration of renewable)

Water Resource Management

- Water quality management
- Waste water reuse
- Water resource infrastructure
- Water resource protection

Food and Agriculture

- Climate change and sustainable crop production
- Advanced trends to improve livestock productivity
- Food processing and food safety

ICT R&D and Infrastructure

- ICT for Social Challenges
  Examples are: ICT for Health, ICT for E-Government, ICT for better Security & Privacy, ICT for better education, ICT for Heritage Documentation and Management, Emerging ICT for digital content creation and management, Smart Cities, ICT Solutions for Smart Factories.
- ICT Emerging Technologies and Infrastructure
  Examples are: Data Science and Cloud Computing, High Performance Computing, Data Systems Management, Embedded Systems and Technologies.

Namibia

MAIN CHALLENGES TO BE ADDRESSED BY THEMATIC AREAS

Thematic Areas	Sub-Themes			
	Food Security	**Health**	**Water, Environment & Bioenergy**	**Education and Socio-Economic Development**
Biosciences	• Drought tolerant crop plants and livestock. • Development of indigenous plants for food and phyto-medicine (IKS). • Climate smart agricultural techniques. • Biotic and abiotic stresses in response to climate change. • Fortification.	• Research on major diseases, including clinical research (STI, TB, malaria, cancer, HIV). • Public Health. • The impact of environmental factors on health. • Nutrition and health. • Animal health and zoonosis. • Maternal health.	• Bioremediation of contaminated soil, water and air. • Second generation biofuels. • Water use and water efficiency in biota. • Mainstreaming biodiversity for sustainable development.	•
ICT	• Food security and adaptive and sustainable resource management (soil, energy, water)	• ICT in the Health Sector. • ICT for social change.	• Climate Change (Environmental Management)	• ICT integration into educational system. • Digitalisation of IKS. • E-Governance.

Thematic Areas	Sub-Themes			
	Food Security	**Health**	**Water, Environment & Bioenergy**	**Education and Socio-Economic Development**
IKS	• IKS and Bio economy. • Food security. • Nutraceuticals.	• African traditional medicine, technology, health and beauty, and cosmetics.	• IKS and Climate Change, Environmental Management, Adaptive and sustainable natural resource management. • IKS and biodiversity conservation.	• IKS Epistemology). • Practices and languages (regional specific). • IKS legislation and public policy. • IKS integration into formal education. • Digitalisation process of IKS.
Social Sciences	• IKS and Food Security.	• Health Wellbeing and Quality of Life. • Health and IKS.	• Environmental Management, Climate Change and Social vulnerability. • Social and Environmental Policy.	• Sustainable Livelihoods: Poverty, Unemployment and Inequality. • Crime Safety and Security. • Nationhood and Social Cohesion. • Education for Sustainable Development.
Energy and Environment		• The impact of environmental factors on health.	• Non-point source pollution for saving the environment. • Soil and water conservation. • Restoration of degraded Land/Ecosystem. • Conservation Agriculture for small holder farmsClimate change and forecasting • Earth Observation (sea, earth and atmosphere linkages). • Bioremediation of contaminated soil, water and air.	• Energy security at all levels (National, Community and Household).Available, affordable, and sustainable Energy for ALL. • Clean energy to minimise environmental pollution. • Environment friendly participation in energy poverty alleviation. • Alleviation of Climate Change by augmenting clean energy.

APPENDIX 2: VITAL STATISTICS OF SADC COUNTRIES

	South Africa
Population	53 675 563
GDP per Capita	$13 100 (2014 est.) $12 900 (2013 est.) $12 600 (2012 est.)
Education Expenditure	6.2% of GDP (2013)
Official Language	IsiZulu (official) 22.7%, IsiXhosa (official) 16%, Afrikaans (official) 13.5%, English (official) 9.6%, Sepedi (official) 9.1%, Setswana (official) 8%, Sesotho (official) 7.6%, Xitsonga (official) 4.5%, siSwati (official) 2.5%, Tshivenda (official) 2.4%, isiNdebele (official) 2.1%, sign language 0.5%, other 1.6% (2011 est.)
Water Area	4620 sq km
Coastline	2798 km
Natural Hazards	prolonged droughts
Land Use	agricultural land: 79.4% arable land 9.9%; permanent crops 0.3%; permanent pasture 69.2% forest: 7.6% other: 13% (2011 est.)
Irrigated Land	16 700 sq km (2012)
Total renewable water resources	51.4 cu km (2011)
Freshwater Withdrawal (Domestic/Industrial/ Agricultural)	total: 12.5 cu km/yr (36%/7%/57%) per capita: 271.7 cu m/yr (2005)
Environment – International Agreement	party to: Antarctic-Environmental Protocol, Antarctic-Marine Living Resources, Antarctic Seals, Antarctic Treaty, Biodiversity, Climate Change, Climate Change-Kyoto Protocol, Desertification, Endangered Species, Hazardous Wastes, Law of the Sea, Marine Dumping, Marine Life Conservation, Ozone Layer Protection, Ship Pollution, Wetlands, Whaling signed, but not ratified: none of the selected agreements
Major Infection Diseases	degree of risk intermediate food or waterborne diseases: bacterial diarrhoea, hepatitis A, and typhoid fever water contact disease: schistosomiasis (2013)
Drinking Water Source:	improved: urban: 99.6% of population rural: 81.4% of population total: 93.2% of population unimproved: urban: 0.4% of population rural: 18.6% of population total: 6.8% of population (2015 est.)
No. of Papers (2012–2014)	44 892
No. of Water-Related Papers (2012–2014)	698

	Angola
Population	19 625 353
GDP Per Capita	$7300 (2014 est.) $6900 (2013 est.) $6500 (2012 est.) note: data are in 2014 US dollars country comparison to the world: 152
Education Expenditure	3.5% of GDP (2010)
Official Language	Portuguese (official), Bantu and other African languages
Water Area	0 sq km
Coastline	1600 km
Natural Hazards	locally heavy rainfall causes periodic flooding on the plateau
Land Use	agricultural land: 47.3% arable land 3.8%; permanent crops 0.2%; permanent pasture 43.3% forest: 46.8% other: 5.9% (2011 est.)
Irrigated Land	860 sq km (2012)
Total Renewable Water Resources	148 cu km (2011)
Freshwater Withdrawal (Domestic/Industrial /Agricultural)	total: 0.71 cu km/yr (45%/34%/21%) per capita: 40.27 cu m/yr (2005)
Environment – International Agreement	party to: Biodiversity, Climate Change, Climate Change-Kyoto Protocol, Desertification, Law of the Sea, Marine Dumping, Ozone Layer Protection, Ship Pollution signed, but not ratified: none of the selected agreements
Major Infection Diseases	degree of risk: very high food or waterborne diseases: bacterial and protozoal diarrhoea, hepatitis A, typhoid fever vectorborne diseases: dengue fever, malaria water contact disease: schistosomiasis animal contact disease: rabies (2013)
Drinking Water Source	improved: urban: 75.4% of population rural: 28.2% of population total: 49% of population unimproved: urban: 24.6% of population rural: 71.8% of population total: 51% of population (2015 est.)
No. of Papers (2012–2014)	169
No. of Water-Related Papers (2012–2014)	0

	Botswana
Population	2 182 719
GDP Per Capita	$17 700 (2015 est.) $17 200 (2014 est.) $16 500 (2013 est.) note: data are in 2015 US dollars country comparison to the world: 96
Education Expenditure	9.5% of GDP (2009)
Official Language	Setswana 78.2%, Kalanga 7.9%, Sekgalagadi 2.8%, English (official) 2.1%, Sesarwa 1.9%, Sempukushu 1.7%, other 5.1%, unspecified 0.2% (2001 est.)
Water Area	15 000 sq km
Coastline	0 km (landlocked)
Natural Hazards	periodic droughts; seasonal August winds blow from the west, carrying sand and dust across the country, which can obscure visibility
Land Use	agricultural land: 45.8% arable land 0.6%; permanent crops 0%; permanent pasture 45.2% forest: 19.8% other: 34.4% (2011 est.)
Irrigated Land	20 sq km (2012)
Total Renewable Water Resources	12.24 cu km (2011)
Freshwater Withdrawal (Domestic/Industrial/ Agricultural)	total: 0.19 cu km/yr (42%/19%/39%) per capita: 107.3 cu m/yr (2005)
Environment – International Agreement	party to: Biodiversity, Climate Change, Climate Change-Kyoto Protocol, Desertification, Endangered Species, Hazardous Wastes, Law of the Sea, Ozone Layer Protection, Wetlands signed, but not ratified: none of the selected agreements
Major Infection Diseases	degree of risk: high food or waterborne diseases: bacterial diarrhoea, hepatitis A, and typhoid fever vectorborne disease: malaria (2013)
Drinking Water Source	improved: urban: 99.2% of population rural: 92.3% of population total: 96.2% of population unimproved: urban: 0.8% of population rural: 7.7% of population total: 3.8% of population (2015 est.)
No. Of Papers (2012–2014)	934
No. Of Water-Related Papers (2012–2014)	31

	Congo
Population	4 755 097
GDP Per Capita	$6800 (2015 est.) $6700 (2014 est.) $6300 (2013 est.) note: data are in 2015 US dollars country comparison to the world: 154
Education Expenditure	6.2% of GDP (2010)
Official Language	French (official), Lingala and Monokutuba (lingua franca trade languages), many local languages and dialects (of which Kikongo is the most widespread)
Water Area	500 sq km
Coastline	169 km
Natural Hazards	seasonal flooding
Land Use	agricultural land: 31.1% arable land 1.6%; permanent crops 0.2%; permanent pasture 29.3% forest: 65.6% other: 3.3% (2011 est.)
Irrigated Land	20 sq km (2012)
Total Renewable Water Resources	832 cu km (2011)
Freshwater Withdrawal (Domestic/Industrial/ Agricultural)	total: 0.05 cu km/yr (69%/26%/4%) per capita: 13.99 cu m/yr (2005)
Environment – International Agreement	party to: Biodiversity, Climate Change, Climate Change-Kyoto Protocol, Desertification, Endangered Species, Hazardous Wastes, Law of the Sea, Ozone Layer Protection, Ship Pollution, Tropical Timber 83, Tropical Timber 94, Wetlands signed, but not ratified: none of the selected agreements
Major Infection Diseases	degree of risk: very high food or waterborne diseases: bacterial and protozoal diarrhoea, hepatitis A, and typhoid fever vectorborne disease: malaria and dengue fever animal contact disease: rabies water contact disease: schistosomiasis (2013)
Drinking Water Source	improved: urban: 95.8% of population rural: 40% of population total: 76.5% of population unimproved: urban: 4.2% of population rural: 60% of population total: 23.5% of population (2015 est.)
No. Of Papers (2012–2014)	490
No. Of Water-Related Papers (2012–2014)	6

	Lesotho
Population	1 947 701
GDP Per Capita	$3000 (2015 est.) $2900 (2014 est.) $2800 (2013 est.) note: data are in 2015 US dollars country comparison to the world: 189
Education Expenditure	13% of GDP (2008)
Official Language	Sesotho (official) (southern Sotho), English (official), Zulu, Xhosa
Water Area	0 sq km
Coastline	0 km (landlocked)
Natural Hazards	periodic droughts
Land Use	agricultural land: 76.1% arable land 10.1%; permanent crops 0.1%; permanent pasture 65.9% forest: 1.5% other: 22.4% (2011 est.)
Irrigated Land	30 sq km (2012)
Total Renewable Water Resources	3.02 cu km (2011)
Freshwater Withdrawal (Domestic/Industrial/ Agricultural)	total: 0.04 cu km/yr (46%/46%/9%) per capita: 21.79 cu m/yr (2000)
Environment – International Agreement	party to: Biodiversity, Climate Change, Climate Change-Kyoto Protocol, Desertification, Endangered Species, Hazardous Wastes, Law of the Sea, Marine Life Conservation, Ozone Layer Protection, Wetlands signed, but not ratified: none of the selected agreements
Major Infection Diseases	N/A
Drinking Water Source	improved: urban: 94.6% of population rural: 77% of population total: 81.8% of population unimproved: urban: 5.4% of population rural: 23% of population total: 18.2% of population (2015 est.)
No. Of Papers (2012–2014)	94
No. Of Water-Related Papers (2012–2014)	3

	Malawi
Population	17 964 697
GDP Per Capita	$1200 (2015 est.) $1100 (2014 est.) $1100 (2013 est.) note: data are in 2015 US dollars country comparison to the world: 220
Education Expenditure	5.4% of GDP (2011)
Official Language	English (official), Chichewa (common), Chinyanja, Chiyao, Chitumbuka, Chilomwe, Chinkhonde, Chingoni, Chisena, Chitonga, Chinyakyusa, Chilambya
Water Area	24,404 sq km
Coastline	0 km (landlocked)
Natural Hazards	N/A
Land Use	agricultural land: 59.2% arable land 38.2%; permanent crops 1.4%; permanent pasture 19.6% forest: 34% other: 6.8% (2011 est.)
Irrigated Land	740 sq km (2012)
Total Renewable Water Resources	17.28 cu km (2011)
Freshwater Withdrawal (Domestic/Industrial/ Agricultural)	total: 1.36 cu km/yr (11%/4%/86%) per capita: 99.86 cu m/yr (2005)
Environment – International Agreement	party to: Biodiversity, Climate Change, Climate Change-Kyoto Protocol, Desertification, Endangered Species, Environmental Modification, Hazardous Wastes, Marine Life Conservation, Ozone Layer Protection, Ship Pollution, Wetlands signed, but not ratified: Law of the Sea
Major Infection Diseases	degree of risk: very high food or waterborne diseases: bacterial and protozoal diarrhoea, hepatitis A, and typhoid fever vectorborne diseases: malaria and dengue fever water contact disease: schistosomiasis animal contact disease: rabies (2013)
Drinking Water Source	improved: urban: 95.7% of population rural: 89.1% of population total: 90.2% of population unimproved: urban: 4.3% of population rural: 10.9% of population total: 9.8% of population (2015 est.)
No. Of Papers (2012–2014)	1 342
No. Of Water-Related Papers (2012–2014)	37

	Mauritius
Population	1 339 827
GDP Per Capita	$19 500 (2015 est.) $18 900 (2014 est.) $18 200 (2013 est.) note: data are in 2015 US dollars country comparison to the world: 88
Education Expenditure	3.7% of GDP (2013)
Official Language	Creole 86.5%, Bhojpuri 5.3%, French 4.1%, two languages 1.4%, other 2.6% (includes English, the official language, which is spoken by less than 1% of the population), unspecified 0.1% (2011 est.)
Water Area	10 sq km
Coastline	177 km
Natural Hazards	cyclones (November to April); almost completely surrounded by reefs that may pose maritime hazards
Land Use	agricultural land: 43.8% arable land 38.4%; permanent crops 2%; permanent pasture 3.4% forest: 17.3% other: 38.9% (2011 est.)
Irrigated Land	190 sq km (2012)
Total Renewable Water Resources	2.75 cu km (2011)
Freshwater Withdrawal (Domestic/Industrial/ Agricultural)	total: 0.73 cu km/yr (30%/3%/68%) per capita: 568.2 cu m/yr (2003)
Environment – International Agreement	party to: Antarctic-Marine Living Resources, Biodiversity, Climate Change, Climate Change-Kyoto Protocol, Desertification, Endangered Species, Environmental Modification, Hazardous Wastes, Law of the Sea, Marine Life Conservation, Ozone Layer Protection, Ship Pollution, Wetlands signed, but not ratified: none of the selected agreements
Major Infection Diseases	N/A
Drinking Water Source	improved: urban: 99.9% of population rural: 99.8% of population total: 99.9% of population unimproved: urban: 0.1% of population rural: 0.2% of population total: 0.1% of population (2015 est.)
No. Of Papers (2012–2014)	479
No. Of Water-Related Papers (2012–2014)	3

	Mozambique
Population	25 303 113
GDP Per Capita	$1300 (2015 est.) $1200 (2014 est.) $1100 (2013 est.) note: data are in 2015 US dollars country comparison to the world: 218
Education Expenditure	5% of GDP (2006)
Official Language	Emakhuwa 25.3%, Portuguese (official) 10.7%, Xichangana 10.3%, Cisena 7.5%, Elomwe 7%, Echuwabo 5.1%, other Mozambican languages 30.1%, other 4% (1997 census)
Water Area	13 000 sq km
Coastline	2470 km
Natural Hazards	severe droughts; devastating cyclones and floods in central and southern provinces
Land Use	agricultural land: 56.3% arable land 6.4%; permanent crops 0.3%; permanent pasture 49.6% forest: 43.7% other: 0% (2011 est.)
Irrigated Land	1180 sq km (2012)
Total Renewable Water Resources	217.1 cu km (2011)
Freshwater Withdrawal (Domestic/Industrial/ Agricultural)	total: 0.88 cu km/yr (26%/4%/70%) per capita: 46.05 cu m/yr (2005)
Environment – International Agreement	party to: Biodiversity, Climate Change, Climate Change-Kyoto Protocol, Desertification, Endangered Species, Hazardous Wastes, Law of the Sea, Ozone Layer Protection, Ship Pollution, Wetlands signed, but not ratified: none of the selected agreements
Major Infection Diseases	degree of risk: very high food or waterborne diseases: bacterial and protozoal diarrhoea, hepatitis A, and typhoid fever vectorborne diseases: malaria and dengue fever water contact disease: schistosomiasis animal contact disease: rabies (2013)
Drinking Water Source	improved: urban: 80.6% of population rural: 37% of population total: 51.1% of population unimproved: urban: 19.4% of population rural: 63% of population total: 48.9% of population (2015 est.)
No. Of Papers (2012–2014)	609
No. Of Water-Related Papers (2012–2014)	13

	Namibia
Population	2 212 307
GDP Per Capita	$11 300 (2015 est.) $10 800 (2014 est.) $10 300 (2013 est.) note: data are in 2015 US dollars country comparison to the world: 132
Education Expenditure	8.5% of GDP (2010)
Official Language	Oshiwambo languages 48.9%, Nama/Damara 11.3%, Afrikaans 10.4% (common language of most of the population and about 60% of the white population), Otjiherero languages 8.6%, Kavango languages 8.5%, Caprivi languages 4.8%, English (official) 3.4%, other African languages 2.3%, other 1.7% note: Namibia has 13 recognised national languages, including ten indigenous African languages and three Indo-European languages (2011 est.)
Water Area	1002 sq km
Coastline	1572 km
Natural Hazards	prolonged periods of drought
Land Use	agricultural land: 47.2% arable land 1%; permanent crops 0%; permanent pasture 46.2% forest: 8.8% other: 44% (2011 est.)
Irrigated Land	80 sq km (2012)
Total Renewable Water Resources	17.72 cu km (2011)
Freshwater Withdrawal (Domestic/Industrial/ Agricultural)	total: 0.29 cu km/yr (25%/5%/70%) per capita: 146 cu m/yr (2002)
Environment – International Agreement	party to: Antarctic-Marine Living Resources, Biodiversity, Climate Change, Climate Change-Kyoto Protocol, Desertification, Endangered Species, Hazardous Wastes, Law of the Sea, Ozone Layer Protection, Wetlands signed, but not ratified: none of the selected agreements
Major Infection Diseases	degree of risk: high food or waterborne diseases: bacterial diarrhoea, hepatitis A, and typhoid fever vectorborne disease: malaria water contact disease: schistosomiasis (2013)
Drinking Water Source	improved: urban: 98.2% of population rural: 84.6% of population total: 91% of population unimproved: urban: 1.8% of population rural: 15.4% of population total: 9% of population (2015 est.)
No. Of Papers (2012–2014)	525
No. Of Water-Related Papers (2012–2014)	20

	Swaziland
Population	1 435 613
GDP Per Capita	$9800 (2015 est.) $9600 (2014 est.) $9400 (2013 est.) note: data are in 2015 US dollars country comparison to the world: 137
Education Expenditure	7.8% of GDP (2011)
Official Language	English (official, used for government business), siSwati (official)
Water Area	160 sq km
Coastline	0 km (landlocked)
Natural Hazards	drought
Land Use	agricultural land: 68.3% arable land 9.8%; permanent crops 0.8%; permanent pasture 57.7% forest: 31.7% other: 0% (2011 est.)
Irrigated Land	498.5 sq km (2003)
Total Renewable Water Resources	4.51 cu km (2011)
Freshwater Withdrawal (Domestic/Industrial/ Agricultural)	total: 1.04 cu km/yr (4%/2%/94%) per capita: 962.1 cu m/yr (2005)
Environment – International Agreement	party to: Biodiversity, Climate Change, Climate Change-Kyoto Protocol, Desertification, Endangered Species, Hazardous Wastes, Ozone Layer Protection signed, but not ratified: Law of the Sea
Major Infection Diseases	degree of risk: intermediate food or waterborne diseases: bacterial diarrhoea, hepatitis A, and typhoid fever vectorborne disease: malaria water contact disease: schistosomiasis (2013)
Drinking Water Source	improved: urban: 93.6% of population rural: 68.9% of population total: 74.1% of population unimproved: urban: 6.4% of population rural: 31.1% of population total: 25.9% of population (2015 est.)
No. Of Papers (2012–2014)	139
No. Of Water-Related Papers (2012–2014)	3

	Zambia
Population	15 066 266
GDP Per Capita	$4300 (2015 est.) $4100 (2014 est.) $3900 (2013 est.) note: data are in 2015 US dollars country comparison to the world: 176
Education Expenditure	1.3% of GDP (2008)
Official Language	Bembe 33.4%, Nyanja 14.7%, Tonga 11.4%, Lozi 5.5%, Chewa 4.5%, Nsenga 2.9%, Tumbuka 2.5%, Lunda (North Western) 1.9%, Kaonde 1.8%, Lala 1.8%, Lamba 1.8%, English (official) 1.7%, Luvale 1.5%, Mambwe 1.3%, Namwanga 1.2%, Lenje 1.1%, Bisa 1%, other 9.2%, unspecified 0.4% note: Zambia is said to have over 70 languages, although many of these may be considered dialects; all of Zambia's major languages are members of the Bantu family (2010 est.)
Water Area	9220 sq km
Coastline	0 km (landlocked)
Natural Hazards	periodic drought; tropical storms (November to April)
Land Use	agricultural land: 31.7% arable land 4.8%; permanent crops 0%; permanent pasture 26.9% forest: 66.3% other: 2% (2011 est.)
Irrigated Land	1559 sq km (2003)
Total Renewable Water Resources	105.2 cu km (2011)
Freshwater Withdrawal (Domestic/Industrial/ Agricultural)	total: 1.57 cu km/yr (18%/8%/73%) per capita: 147 cu m/yr (2002)
Environment – International Agreement	party to: Biodiversity, Climate Change, Climate Change-Kyoto Protocol, Desertification, Endangered Species, Hazardous Wastes, Law of the Sea, Ozone Layer Protection, Wetlands signed, but not ratified: none of the selected agreements
Major Infection Diseases	degree of risk: very high food or waterborne diseases: bacterial and protozoal diarrhoea, hepatitis A, and typhoid fever vectorborne diseases: malaria and dengue fever water contact disease: schistosomiasis animal contact disease: rabies (2013)
Drinking Water Source	improved: urban: 85.6% of population rural: 51.3% of population total: 65.4% of population unimproved: urban: 14.4% of population rural: 48.7% of population total: 34.6% of population (2015 est.)
No. Of Papers (2012–2014)	1 097
No. Of Water-Related Papers (2012–2014)	5

	Tanzania
Population	51 045 882
GDP Per Capita	$3,000 (2015 est.) $2 800 (2014 est.) $2,600 (2013 est.) note: data are in 2015 US dollars country comparison to the world: 188
Education Expenditure	6.2% of GDP (2010)
Official Language	Kiswahili or Swahili (official), Kiunguja (name for Swahili in Zanzibar), English (official, primary language of commerce, administration, and higher education), Arabic (widely spoken in Zanzibar), many local languages note: Kiswahili (Swahili) is the mother tongue of the Bantu people living in Zanzibar and nearby coastal Tanzania; although Kiswahili is Bantu in structure and origin, its vocabulary draws on a variety of sources including Arabic and English; it has become the lingua franca of central and eastern Africa; the first language of most people is one of the local languages
Water Area	61 500 sq km
Coastline	1424 km
Natural Hazards	flooding on the central plateau during the rainy season; drought volcanism: limited volcanic activity; Ol Doinyo Lengai (elev. 2962 m) has emitted lava in recent years; other historically active volcanoes include Kieyo and Meru
Land Use	agricultural land: 43.7% arable land 14.3%; permanent crops 2.3%; permanent pasture 27.1% forest: 37.3% other: 19% (2011 est.)
Irrigated Land	1843 sq km (2003)
Total Renewable Water Resources	96.27 cu km (2011)
Freshwater Withdrawal (Domestic/Industrial/ Agricultural)	total: 5.18 cu km/yr (10%/0%/89%) per capita: 144.7 cu m/yr (2002)
Environment – International Agreement	party to: Biodiversity, Climate Change, Climate Change-Kyoto Protocol, Desertification, Endangered Species, Hazardous Wastes, Law of the Sea, Ozone Layer Protection, Wetlands signed, but not ratified: none of the selected agreements
Major Infection Diseases	degree of risk: very high food or waterborne diseases: bacterial diarrhoea, hepatitis A, and typhoid fever vectorborne diseases: malaria, dengue fever, and Rift Valley fever water contact diseases: schistosomiasis and leptospirosis animal contact disease: rabies (2013)

	Tanzania
Drinking Water Source	improved: urban: 77.2% of population rural: 45.5% of population total: 55.6% of population unimproved: urban: 22.1% of population rural: 56% of population total: 46.8% of population (2015 est.)
No. Of Papers (2012–2014)	2858
No. Of Water-Related Papers (2012–2014)	54

	Zimbabwe
Population	14 229 541
GDP Per Capita	$2100 (2015 est.) $2100 (2014 est.) $2000 (2013 est.) note: data are in 2015 US dollars country comparison to the world: 200
Education Expenditure	2% of GDP (2010)
Official Language	Shona (official; most widely spoken), Ndebele (official, second most widely spoken), English (official; traditionally used for official business), 13 minority languages (official; includes Chewa, Chibarwe, Kalanga, Koisan, Nambya, Ndau, Shangani, sign language, Sotho, Tonga, Tswana, Venda, and Xhosa)
Water Area	3910 sq km
Coastline	0 km (landlocked)
Natural Hazards	recurring droughts; floods and severe storms are rare
Land Use	agricultural land: 42.5% arable land 10.9%; permanent crops 0.3%; permanent pasture 31.3% forest: 39.5% other: 18% (2011 est.)
Irrigated Land	1735 sq km (2003)
Total Renewable Water Resources	20 cu km (2011)
Freshwater Withdrawal (Domestic/Industrial/ Agricultural)	total: 4.21 cu km/yr (14%/7%/79%) per capita: 333.5 cu m/yr (2002)
Environment – International Agreement	party to: Biodiversity, Climate Change, Desertification, Endangered Species, Law of the Sea, Ozone Layer Protection signed, but not ratified: none of the selected agreements

	Zimbabwe
Major Infection Diseases	degree of risk: very high food or waterborne diseases: bacterial and protozoal diarrhoea, hepatitis A, and typhoid fever vectorborne diseases: malaria and dengue fever water contact disease: schistosomiasis animal contact disease: rabies (2013)
Drinking Water Source	improved: urban: 97% of population rural: 67.3% of population total: 76.9% of population unimproved: urban: 3% of population rural: 32.7% of population total: 23.1% of population (2015 est.)
No. Of Papers (2012–2014)	1300
No. Of Water-Related Papers (2012–2014)	47

	***Seychelles**
Population	92 430
GDP Per Capita	$27 000 (2015 est.) $26 000 (2014 est.) $25 200 (2013 est.) note: data are in 2015 US dollars country comparison to the world: 67
Education Expenditure	3.6% of GDP (2011)
Official Language	Seychellois Creole (official) 89.1%, English (official) 5.1%, French (official) 0.7%, other 3.8%, unspecified 1.4% (2010 est.)
Water Area	0 sq km
Coastline	491 km
Natural Hazards	lies outside the cyclone belt, so severe storms are rare; occasional short droughts
Land Use	agricultural land: 6.5% arable land 2.2%; permanent crops 4.3%; permanent pasture 0% forest: 88.5% other: 5% (2011 est.)
Irrigated Land	2.6 sq km (2003)
Total Renewable Water Resources	N/A
Freshwater Withdrawal (Domestic/Industrial/ Agricultural)	N/A

	*Seychelles
Environment – International Agreement	party to: Biodiversity, Climate Change, Climate Change-Kyoto Protocol, Desertification, Endangered Species, Hazardous Wastes, Law of the Sea, Marine Dumping, Ozone Layer Protection, Ship Pollution, Wetlands signed, but not ratified: none of the selected agreements
Major Infection Diseases	N/A
Drinking Water Source	improved: urban: 95.7% of population rural: 95.7% of population total: 95.7% of population unimproved: urban: 4.3% of population rural: 4.3% of population total: 4.3% of population (2015 est.)
No. Of Papers (2012–2014)	128
No. Of Water-Related Papers (2012–2014)	2

	Madagascar
Population	24 430 325 (July 2016 est.)
GDP Per Capita	$35.44 billion (2015 est.) $34.39 billion (2014 est.) $33.29 billion (2013 est.) note: data are in 2015 US dollars country comparison to the world: 121
Education Expenditure	
Official Language	French (official), Malagasy (official), English
Water Area	
Coastline	4828 km
Natural Hazards	periodic cyclones; drought; and locust infestation volcanism: Madagascar's volcanoes have not erupted in historical times
Land Use	agricultural land: 71.1% arable land 6%; permanent crops 1%; permanent pasture 64.1% forest: 21.5% other: 7.4% (2011 est.)
Irrigated Land	10 860 sq km (2012)
Total Renewable Water Resources	N/A
Freshwater Withdrawal (Domestic/Industrial/ Agricultural)	N/A

	Madagascar
Environment – International Agreement	party to: Biodiversity, Climate Change, Climate Change-Kyoto Protocol, Desertification, Endangered Species, Hazardous Wastes, Law of the Sea, Marine Life Conservation, Ozone Layer Protection, Ship Pollution, Wetlands signed, but not ratified: none of the selected agreements
Major Infection Diseases	degree of risk: very high food or waterborne diseases: bacterial diarrhoea, hepatitis A, and typhoid fever vectorborne diseases: malaria and dengue fever water contact disease: schistosomiasis animal contact disease: rabies (2016)
Drinking Water Source	improved: urban: 81.6% of population rural: 35.3% of population total: 51.5% of population unimproved: urban: 18.4% of population rural: 64.7% of population total: 48.5% of population (2015 est.)
No. Of Papers (2012–2014)	257
No. Of Water-Related Papers (2012–2014)	2

APPENDIX 3: SURVEY OF STAKEHOLDERS QUESTIONNAIRE

Survey: Science Diplomacy for Transboundary Water Resource Management

This survey is part of the WRC funded effort to assess the South Africa–SADC collaboration and its desirability

(See letter from WRC). The intention of the effort is to provide the WRC and the water research and development community with insights into science diplomacy and the existing collaborative base. Research collaboration is an important component in science diplomacy.

Please complete the questionnaire and email it to Prof A Pouris at apouris@icon.co.za or anastassios.pouris@up.ac.za. For any further information please do not hesitate to contact Prof Pouris at 083-630 5996.

Name of person completing the form					
Position within the organisation		**Tel:**		**Email:**	
Name of your Organisation					
Collaboration with African countries in which you participated					

A. What factors facilitate or inhibit research collaboration in the field of water in SADC region?

	Facilitate 5	Avg. 4	3	2	Strongly Inhibit 1
1. Assistance/advice from funding agencies					
2. Assistance/advice from your Institution					
3. Your geographical location					

4. Pre-established relationship with partners					
5. Ability to find new partners					
6. Availability of funds					
7. Availability of postgraduate students					
8. Availability/expertise of partner					
9. Availability/expertise in South Africa					

10. Others, Please specify

B. Do you consider that research collaboration in the field of water is desirable?

C. How South Africa–SADC collaboration in the field of water research can be strengthened?

THANK YOU!