THE CONTRIBUTION OF THE WATER RESEARCH FUND FOR SOUTHERN AFRICA (WARFSA) TO KNOWLEDGE PRODUCTION AND POLICY IN THE SADC WATER SECTOR

by
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DECLARATION

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Date: April 2019

Abstract

Integrated Water Resource Management (IWRM) has been adopted by member states in the Southern African Development Community (SADC) as the process to best manage water resources, with research as a major component in the process. Moreover, it is increasingly a requirement for universities and research institutions to indicate the benefit of their research. With various universities and research institutions (and varying levels of resources) conducting water research in the SADC region, outputs from the Water Research Fund of Southern Africa (WARFSA) provides an opportunity to analyse the impact of such research, given the regional nature of the programme. Moreover, given that the WARFSA was implemented between 1999 and 2007, the time-lag provide an opportunity to analyse the contribution to knowledge production, and specifically the scientific (citation) impact and, given its mandate from the SADC ministers, policy uptake. However, as no mechanism was put in place to attribute and monitor economic, ecological and social benefits from the WARFSA, this was excluded from the study.

Applying a mixed methods approach, various aspects relating to water research knowledge production and policy uptake of research were investigated, resulting in this thesis being divided into three parts. Part A framing the research project, Part B presenting a SADC water sectoral analysis and analysis of knowledge production in the SADC region, and Part C presenting results from the analysis of knowledge production and policy aspects of the Water Research Fund for Southern Africa (WARFSA). Research methodologies comprised a literature review to determine a theoretical framework, and an analysis of previous empirical studies on the scientific contribution of water research in the SADC region, and research on knowledge produced and citation impact. In addition, scientometric techniques were used to analyse citation data from water publications in the SADC region between 1980 and 2016, and knowledge produced from research projects funded through the WARFSA. Lastly, interviews were conducted with researchers and stakeholders involved in the WARFSA programme, to ascertain policy uptake from the WARFSA. As the study has shown, researchers affiliated with South African universities and research institutions have produced 84% of water research in the region, and for this reason, bibliometric data was first analysed to include citation data from all SADC countries, then South African citation data on its own, which was followed by SADC countries were South African citation data was excluded (referred to in the study as 'SADC-ExSA' countries).

As already mentioned, one of the main findings from the study was that water research in the SADC region was mainly produced by South African researchers. However, on a per capita basis, researchers from Botswana, followed by the Seychelles and then South Africa, Namibia and Zimbabwe had produced the most water research. As most previous bibliometric studies were conducted on the South African water sector, findings from the analysis of citation data

from South African researchers supported the previous bibliometric studies. The analysis of citation data from SADC-ExSA countries provided a clearer picture of the contribution the WARFSA programme has made to knowledge production in the region, especially when comparing citation data before and after the implementation period of WARFSA in the early 2000s. It was further evident that most of the 78 research projects funded through the WARFSA were implemented in SADC-ExSA countries, and benefited these countries most. If one were to consider only water research output in SADC-ExSA countries during the implementation period of WARFSA between 1999 and 2007, a significant increase is observed during this period. In addition, the study highlights the significance of the annual WaterNet/WARFSA/GWP SA symposium, which was initially presented along with WARFSA and continued after the initial two phases of the WARFSA. The study further highlighted the large contribution of external donor funding towards water research in especially SADC-ExSA countries, which some could argue borders on a dependency on external funding, when compared to more local support for water research in South Africa.

In terms of the contribution of the WARFSA towards policy uptake, the study highlighted the gap between the research community and policymakers, the mixed involvement of practitioners and policymakers in the research projects and the positive role of intermediaries and knowledge brokers in the WARFSA-funded projects. Finally, the study highlighted the challenges in attributing research findings to policy relevance.

In conclusion, this study recommends the potential adaptation of the HERG Payback framework to reflect ecological benefits resulting from research better. Moreover, such adaptations to the HERG Payback framework could strengthen future phases of the WARFSA to identify, monitor and report the benefits of research. In addition, such a monitoring function should be established outside research projects, to support research projects better.

Opsomming

Geïntegreerde Waterhulpbronbestuur (GWHB) is deur die Suider-Afrikaanse Ontwikkelingsgemeenskap (SAOG) aanvaar as ŉ proses om waterhulpbronne te bestuur, met navorsing wat ŉ sleutelkomponent in die proses vervul. Daar word ook al hoe meer van universiteite en navorsingsinstellings verwag om die voordele van navorsing aan te dui. In die SAOG is daar dan ook verskeie universiteite en navorsinginstellings wat waternavorsing onderneem, met verskillende vlakke van toegang tot hulpbronne. Gegewe hierdie streeksverband, bied die Waternavorsingsfonds vir Suidelike Afrika (WNFSA) die geleentheid om die bydrae tot kennisproduksie van sodanige waternavorsing te ondersoek. Die WNFSA is tussen 1999 en 2007 geïmplementeer, wat die geleentheid bied om die bydrae wat die fonds tot die skep van kennis gemaak het, te ondersoek, en in die besonder die wetenskaplike (sitasie) impak en, gegewe die SAOG- ministeriële mandaat, die bydrae tot beleidsformulering. Daar is egter geen meganisme beskikbaar gestel om die ekonomiese, ekologiese en maatskaplike voordele van die navorsing te identifiseer en te monitor nie, en daarom het hierdie aspekte nie deel uitgemaak van die studie nie.

Deur van verskeie navorsingsmetodes gebruik te maak, is aspekte wat verband hou met die skep van kennis en beleidsformulering van waternavorsing ondersoek, wat daartoe gelei het dat hierdie tesis in drie dele verdeel is. In Afdeling A word die afbakening van die studie uiteengesit. Afdeling B bied ŉ oorsig oor die SAOG-watersektor en ŉ analise van kennisproduksie in die SAOG, terwyl Afdeling C die resultate van kennis wat deur die WNFSA gegenereer is, bied asook sekere beleidsaspekte wat met WNFSA verband hou. Navorsingsmetodes het ŉ literatuurstudie om die teoretiese raamwerk vas te stel, ingesluit deurdat vorige empiriese studies wat kennisproduksie van waternavorsing in die SAOG ondersoek het, asook navorsing wat verband hou met kennisproduksie en sitasie-impak ondersoek is. Daar is verder wetenskaplike tegnieke gebruik om sitasie-data van waternavorsingpublikasies wat tussen 1980 en 2016 gepubliseer is te analiseer, asook waternavorsingpublikasies wat vanuit die WNFSA gepubliseer is. Laastens is onderhoude met navorsers en rolspelers wat by die WNFSA betrokke was, gevoer om beleidsaspekte te ondersoek. Omdat navorsers wat met Suid-Afrikaanse universiteite geaffilieer is, 84% van alle waternavorsing wat ondersoek is, gepubliseer het, is die bibliometriese data eerstens geanaliseer om sitasie-data van alle SAOG-lande in te sluit, gevolg deur die analise van slegs Suid-Afrikaanse sitasie-data, wat daarna gevolg is deur die analise van sitasie-data van SAOG-lande waarvan Suid-Afrikaanse data uitgesluit is (in die studie na verwys as ‘SADC-ExSA’-lande).

Soos reeds genoem, was een van die hoofbevindinge na aanleiding van die studie dat waternavorsing in die SAOG-streek tot dusver meestal deur Suid-Afrikaanse navorsers gedoen

is. Wanneer data egter op ŉ per kapita-basis voorgestel word, het navorsers van Botswana, gevolg deur die Seychelle-eilande en dan Suid-Afrika, Namibië en Zimbabwe die meeste waternavorsing geproduseer. Bevindinge met betrekking tot die analise van Suid-Afrikaanse sitasie-data was ook in oorstemming met verskeie ander vorige bibliometriese studies, wat grotendeels op die Suid-Afrikaanse watersektor gefokus het. Die analise van sitasie-data van SADC-ExSA-lande skep ŉ duideliker beeld van die bydrae wat die WNFSA-program tot die skep van kennis in die streek gehad het, veral wanneer sitasie data van voor en ná die implementeringstydperk van die WNFSA in die vroeë 2000s ontleed en vergelyk word. Daar is verder bevind dat die meeste van die 78 navorsingsprojekte wat deur die WNFSA befonds is, in SADC-ExSA-lande geïmplementeer is, en hierdie lande die meeste bevoordeel het. Indien slegs waternavorsing van SADC-ExSA-lande oorweeg word, word ŉ opmerklike toename in publikasieuitsette waargeneem, in die besonder vir die tydperk tussen 1999 en 2007, wat ooreenstem met die implementeringstydperk van die WNFSA. Die studie het verder die opmerklike rol wat die jaarlikse WaterNet/WARFSA/GWP SA-simposium speel beklemtoon. Dié simposium is aanvanklik saam met en daarna voortgesit ná die implementeringstydperk van die WNFSA. Die studie beklemtoon verder die aansienlike bydrae wat eksterne befondsers tot waternavorsing in SADC-ExSA-lande maak. Hierdie bydrae wat volgens sommige mense aan ŉ afhanklikheid grens, veral wanneer meer plaaslike ondersteuning in Suid-Afrika opgemerk word.

Die bydrae van die WNFSA tot beleidsaspekte word gestaaf deur die gaping tussen die navorsingsgemeenskap en besluitnemers, die gemengde betrokkenheid van praktisyns en beleidvormers by navorsingsprojekte en die positiewe rol wat tussengangers en kennis-makelaars in die WNFSA-befondsde projekte gespeel het. Laastens beklemtoon die studie die uitdagings wat ondervind word om die invloed wat navorsingsbevindings op beleidsaspekte het, te identifiseer.

Ter afsluiting beveel die studie aanpassing van die HERG Payback-raamwerk aan om ook die ekologiese voordele wat navorsing teweeg kan bring, te reflekteer. Verder kan sodanige aanpassings toekomstige fases van die WNFSA versterk om navorsingsvoordele te identifiseer, te monitor en te rapporteer. Daarbenewens moet so ŉ moniteringsfunksie buite navorsingsprojekte tot stand kom om navorsingsprojekte beter te ondersteun.

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Finally, I would further like to thank my wife Nadine, and children Reinhardt, Hilde and Isabella, for their patience and never-ending support over the years.

My journey with this PhD

In 2013, our office at the Stellenbosch University was tasked to develop a new Implementation Plan for the WARFSA, with the objective of reviving the programme. Following discussions with colleagues involved in the initial WARFSA programme, comments such as "*the WARFSA had such an impact on the SADC water sector*", and "*it was such a pity the WARFSA programme came to an end as it supported so many students*" made me to think about the research utilisation resulting from the initial programme. I started asking questions such as: "*but what does impact mean? Are we talking about social impact? Surely, it is known that the WARFSA supported researchers, but what about the utilisation of WARFSA-funded research by the policy-makers, the economic- and ecological impact of research? And how do social-ecological impact relate to research impact and how could one measure such?*"

Further, should the WARFSA programme be revived, what could we learn in terms of research utilisation from the initial phases and how can we take these lessons learnt, further and apply it to the WARFSA programme in future?

Following initial discussions with Prof. Johann Mouton of the Centre for Research on Evaluation, Science and Technology (CREST) at Stellenbosch University, a realisation dawned on us that the discussions could result in a PhD topic, which was subsequently formulated and approved by Senate in early 2014. Thus, the start of this academic endeavour of discovery with Prof. Johann Mouton as supervisor, and Prof. Eugene Cloete as co-supervisor ensued.

I soon realised that the term "research impact" has different meanings for different people and, without over-simplifying the issue, I realised that academics at a University could define research impact in terms of knowledge production of journal articles, dissertations, book chapters etc. Policy-makers and practitioners want to measure research impact in terms of its translation into policy and practice, independent from the number of scientific articles was published, and "society" want to know how research have improved their daily life through in terms of socio-economic benefits. Researchers, policy makers and society are sometimes aware that research could translate into ecological benefits, which could also translate into socio-ecological benefits. A robust and comprehensive theoretical research impact framework was thus required. Initial investigations led me to the Payback Framework which was originally developed in 1996 by the Health Economics Research Group (HERG) at Brunel University London (M. Buxton & Hanney, 1996). I further had the opportunity to visit Prof. Stephen Hanney at Brunel University in April 2015, which provided insights into the use of the Payback Framework.

During the discussions, it became apparent that the time-lag since the completion of the WARFSA in 2007 would become a challenge in obtaining meta-data such as project reports on the research projects. Moreover, I foresaw challenges related to the attribution of research utilisation to specific research projects, given this time-lag – these challenges would be confirmed later during this study project.

Finally, given the objective of the WARFSA to fund scientific research projects, and as the programme was mandated by the SADC ministers of water, it was decided to limit the study to benefits relating to knowledge production and the policy dimensions. This is not to say that societal-, economical- or ecological benefits could not have resulted from the WARFSA-funded projects, but that this could be investigated in future research.

Over the course of this research project, I have participated in various workshops and conferences, which influenced elements of this study, and where I have been able to present preliminary results.

Symposiums, conferences and workshops associated with this study:

1. World Water Week. August 2015. Stockholm, Sweden. Attended as delegate.
2. 3rd ChinAfrica Water Forum Conference. University of the Western Cape, South Africa. August 2015. Presentation on the AU/NEPAD Networks of Water Centres of Excellence and how the Payback Framework forms a framework for research impact within the programme.
3. 16th WaterNet/WARFSA/GWP SA Symposium, Mauritius. October 2015. Special session: *The Payback-Eco Framework: Measuring the Impact of Scientific Research in the Water Sector and experiences from the WARFSA Funded Research (1999-2014).*
4. 17th WaterNet/WARFSA/GWP SA Symposium, Gaborone, Botswana. October 2016. Conference Proceeding. *Scientific knowledge production in the SADC water sector.*
5. PECS 2015 Conference. November 2015. Social-ecological dynamics in the Anthropocene. Spier, South Africa. Attended as a delegate.

As a PhD candidate at CREST, I had the opportunity to particpate in workshops, which has contributed towards this research project:

1. Science Utilisation and Impact. 8–9 October 2013. Prof. Johann Mouton and Dr. Nelius Boshoff.
2. Introduction to Scientometrics; 17–18 March 2014; Lecturers: Prof. Johann Mouton and Prof. Robert Tijssen.

3. Advanced Bibliometrics and Scientometrics ; 19–20 March 2014; Presenter: Prof. Robert Tijssen.
4. Research Evaluation; 8–9 May 2014; Presenters: Prof. Stefan Kuhlmann and Prof. Johann Mouton.
5. Assessing the impact of research; 10–12 May 2014; Presenters: Prof. Johann Mouton and Dr. Nelius Boshoff.
6. Research Systems in Africa; August 2014; Presenters: Prof. Johann Mouton; Dr. Nelius Boshoff and Prof. Rasigan Maharajh.
7. Africa Doctoral Academy (ADA). 6th Annual Summer School. 29 June 2015 to 3 July 2015. Designing, doing and publishing case studies. Presenter Prof. Michael Gibbert - University of Lugano. [Received a scholarship].
8. Facilitated a three-day workshop at Africa Doctoral Academy (ADA). 5th Annual Summer School in Research Methodology. 23 June 2014 to 4 July 2014. Using the Docear MindMapping software as a research tool.

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PART B: SECTOR ANALYSIS AND KNOWLEDGE PRODUCTION IN THE SADC WATER SECTOR

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Abbreviations and acronyms

AAGR	average annual growth rate
ACCESS	Applied Centre for Climate & Earth Systems Sciences
ACF	Advocacy Coalition Framework
ADB	African Development Bank
AfricaSAN	AfricaSan is an AMCOW initiative to help agencies and governments shape strategies for action to realise the eThekwini Commitments on sanitation in Africa
AfWA	African Water Association
AGR	annual growth rate
AI	activity index
AIO	Africa Innovation Outlook
AMCOST	African Ministerial Council on Science and Technology
AMCOW	African Ministers' Council on Water
ANBO	African Network of River Basin Organisations
ANEW	African Network on Water
ARIPO	African Regional Intellectual Property Organization
AU	African Union
AU/NEPAD	African Union/New Partnership for Africa's Development
AWF	African Water Facility
AWS	automatic weather stations
BMBF	Bundesministerium für Bildung und Forschung (German Federal Ministry of Education and Research)
BOTEC	Botswana Technology Centre
BRICS	Brazil, Russia, India, China and South Africa
Cap-Net	Cap-Net is an international network for capacity development in sustainable water management
CEANWATCE	Central and East African Network of Water Centres of Excellence
CIPC	Companies and Intellectual Property Commission
COMESA	Common Market for Eastern & Southern Africa
CPC	Cooperative Patent Classification
CPUT	Cape Peninsula University of Technology
CREST	Centre for Research on Evaluation, Science and Technology at Stellenbosch University
CSIR	Council for Scientific and Industrial Research
CUT	Chinhoyi University of Technology
D&U	Dissemination & Utilisation
DANIDA	Danish International Development Agency
DFID	Department of International Development (United Kingdom)
DRC	Democratic Republic of Congo
DST	Department of Science and Technology (South Africa)
DUT	Durban University of Technology
DWPI	Derwent World Patents Index
EC	European Commission
ECOWAS	Economic Community of West African States
ESRC	Economic and Social Research Council (United Kingdom)
EU	European Union
FAIT	Framework to Assess the Impact from Translational health research

GDP	gross domestic product
GERD	gross expenditure on research and development
GIS	geographical information system
GTZ	Deutshe Gesellschaft für Technische Zusammenarbeit (GTZ). Has subsequently changed it name to Gesellschaft für International Zusammenarbeit (GIZ)
GWP	Global Water Partnership
GWP SA	Global Water Partnership Southern Africa
HERG	Health Economics Research Group
HSRC	Human Sciences Research Council
IAHS	International Association of Hydrological Sciences
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
ICT	information and communication technology
IDRC	Canadian International Development Research Centre
IFS	International Foundation for Science
IHE	Institute for Water [Hydro] Education
IOM	impact-orientated monitoring
IPC	International Patents Classification
IUCN	International Union for Conservation of Nature
IWA	International Water Association
IWMI	International Water Management Institute
IWRM	Integrated Water Resource Management
IWSD	Institute of Water and Sanitation Development
JCR	journal citation reports
JIF	journal impact factor
KB	knowledge brokering
KSA	key strategic area
LTER	long-term environmental research
MRC	Medical Research Council
NEPAD	New Partnership for Africa's Development
NGO	non-government organisation
NMU	Nelson Mandela University (previously NMMU)
NMMU	Nelson Mandela Metropolitan University (now NMU)
NPM	New Public Management
NRF	National Research Foundation
NSERC	Natural Sciences and Engineering Research Council (Canada)
NTBFs	new technology-based firms
NUST	Namibia University of Science and Technology
OECD	Organisation for Economic Co-operation and Development
ORASECOM	Orange-Senqu River Commission
PCE	*Physics and Chemistry of the Earth* (scientific journal)
PDI	previously disadvantaged individual
PI	principal investigator
PPP	public–private partnership
PSP	private sector participation
R&D	research and development
RBO	River Basin Organisation
RIF	research impact framework
RISDP	Regional Indicative Strategic Economic Plan (SADC)

RoE	research on evaluation
RSAP	Regional Strategic Action Plan
RSAP-IWRM	Regional Strategic Action Plan on Integrated Water Resources Development and Management [SADC]
S&T	Science and Technology
SADC	Southern African Development Community
SADCC	Southern African Development Coordination Conference
SADC-ExSA	SADC countries excluding South Africa
SANWATCE	Southern African Network of Water Centres of Excellence
SASSCAL	Southern African Science Service Centre for Climate Change and Adaptive Land Management
SCI	Science Citation Index
Sida	Swedish International Development Agency
SIRDC	Scientific and Industrial Research and Development Centre
SIWI	Stockholm International Water Institute
STI	science, technology and innovation
SU	Stellenbosch University
SUA	Sokoine University of Agriculture
SWA	Sanitation and Water for All
TIA	technology innovation agency
TTO	technology transfer office
TUT	Tshwane University of Technology
UB	University of Botswana
UCT	University of Cape Town
UDSM	University of Dar es Salaam
UEM	Eduardo Mondlane University
UFS	University of the Free State
UJ	University of Johannesburg
UKCDR	United Kingdom Collaborative on Development Research
UK-REF	United Kingdom’s Research Excellence Framework
UKZN	University of KwaZulu-Natal
UL	University of Limpopo
UNDP	United Nation Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNESCO IHE	UNESCO Institute for Water [Hydro] Education
UNIMA	University of Malawi
UNIZULU	University of Zululand
UP	University of Pretoria
UR	University of Rwanda
USPTO	United States Patent and Trademark Office
UT	University of Technology
UV	University of Venda
UWC	University of the Western Cape
UZ	University of Zimbabwe
WANWATCE	Western African Network of Water Centres of Excellence
WARFSA	Water Research Fund for Southern Africa
WASH	Water, Sanitation and Health
WCoEs	Water Centres of Excellence
WDM	Water Demand Management

WISA	Water Institute of Southern Africa
WoS	Web of Science™
WRC	Water Research Commission
WWAP	World Water Assessment Programme
WWDR	World Water Development Report
YWP ZA	South African Young Water Professionals
ZACPLAN	Zambezi River System Action Plan
ZAMCOM	Zambezi Watercourse Commission

PART A

FRAMING THE RESEARCH PROJECT AND THE RESEARCH METHODOLOGY

Chapter 1

BACKROUND AND STATEMENT OF THE PROBLEM

1.1 Introduction

The Water Research Fund for Southern Africa (WARFSA) was established as a Southern African Development Community-[1] (SADC-) associated programme in February 1999 with the purpose of building research capacity among regional institutions and individuals, as well as to promote the utilisation of research results to support the practice and understanding of the concept of integrated water resource management (IWRM) in the sub-region. Having the South African Water Research Commission (WRC) as a benchmark of what can be achieved, WARFSA, as a major regional capacity development initiative, had the potential to influence the sub-region, in supporting scientific research and the understanding IWRM as a process. Moreover, since its inception, WARFSA was closely associated with the establishment of the SADC Regional Strategic Action Plan on Integrated Water Resource Management and Development (known as the RSAP I) (see SADC, 2016). The RSAP was implemented between 1999 and 2004 and has subsequently been updated in five-year cycles, with the RSAP II (2005 to 2010), RSAP III (2011 to 2015) and the latest update, RSAP IV for the period 2016 to 2021 (see SADC, 2016). Since the RSAP I, this association provided the WARFSA with its political support, and now fully entrenched as a mechanism to support research capacity development in the region.

With an initial implementation of two phases, WARFSA directly supported 78 water-related research projects between 1999 and 2007. During the first two phases, the Swedish International Development Agency (Sida), and to a lesser extent, the Danish International Development Agency (DANIDA) financially supported the WARFSA, while administered by the Institute of Water and Sanitation (IWSD) in Zimbabwe. In 2002, an evaluation of the fund was conducted, with specific objectives being:

1) the evaluation of overall achievement of the objectives of the fund;
2) analysing the efficiency of the managerial set-up of the fund; and
3) making recommendations on improvements with regard to the set-up and management of the fund (Krugmann, 2002).

However, of importance, the evaluation focussed on the management of the fund, with the influence of the WARFSA and related outputs not evaluated.

Following the completion of WARFSA Phase II in the mid-2000s, the WARFSA lay dormant up until 2013, when the SADC Water Division initiated a process to revive the WARFSA.

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[1] SADC countries are Botswana, Swaziland, Zimbabwe, Namibia, Lesotho, Mozambique, Tanzania, Malawi, South Africa, Seychelles, Mauritius, Zambia, Madagascar, the Democratic Republic of Congo and Angola.

1.2 Problem statement

With many universities and research institutions conducting research, either with public or private funding, research projects and programmes are required to place a strong emphasis on presenting evidence of the results achieved through the research they undertake (United Kingdom Collaborative on Development Research [UKCDR], 2013). As a consequence, various conceptual frameworks have been developed on research use and how research could be used to analyse the influence of the research, with research on evaluation (RoE) increasing over the past decade and contributing towards an ever-increasing literature base (Coryn et al., 2017). As evident in the body of knowledge, it is now clear that research conducted by universities and research institutions could have scientific, policy, economic, social and ecological benefits.

Given the focus of this project on the SADC region, various institutions are conducting research on topics related to the water sector. In recent years, South Africa has spent three times as much as other sub-Saharan countries on research and development (expressed as gross expenditure on R&D [GERD] (UNESCO, 2011). It is therefore clear that many South African universities and research institutions are better resourced than their counterparts in the region, which leads to disparities in research addressing issues related to the water sector. Over the past couple of years, institutions such as the Water Research Commission (WRC) have initiated research projects to start evaluating the knowledge influence of research in the sector (Jacobs, Pouris & Naidoo, 2014; Pouris, 2013; 2015). These studies however focussed on South Africa, and primarily on the scientific benefits and knowledge outputs from research and did not necessarily assess the broader influence of research.

As a SADC regional programme, WARFSA provided an opportunity to analyse the influence such a programme had in the SADC water sector, since its implementation in the early 2000s. However, the time lag since the WARFSA programme ended in the mid-2000s, provides opportunities and constraints in analysing the scientific, policy, economic, ecological and social benefits of the WARFSA programme. As a time lag often occurs between the time when the research outputs are produced and the actual citing of such research, the scientific influence of WARFSA-funded research projects should be assessed. Moreover, policy aspects should be analysed, if a sufficient number of researchers associated with the WARFSA-funded research projects could be interviewed. Should an insufficient number of researchers be available for interviews, the study could be undertaken as an exploratory study, identifying themes which contribute (or not contribute) to the translation of research into policy and practitioner uptake could be identified, rather than qualitatively identify how many projects translated into some form of policy or practitioner uptake. Moreover, as no mechanism was put in place to attribute the influence of the WARFSA funded projects to various impact dimensions, assessing the economic, ecological and social benefits derived from WARFSA-funded projects would be more difficult.

1.3 Aim of the study and hypotheses

The main thesis of this study was that the WARFSA programme had a positive impact on knowledge production in the SADC water sector. With this thesis in mind, the aim of the study was to assess the output and production of knowledge under the WARFSA programme. More specifically, the two main objectives of the study were to assess the scientific (citation) impact of the production of such knowledge as well as the policy uptake and impact of it.

To address the first objective, the results of the following quantitative analyses are presented:

- the context of knowledge production in the SADC water sector, with comparisons of knowledge production in the SADC in relation to the African continent and global water research as well as the devotion of the relevant SADC countries to water research is presented;
- focussing on water publications in SADC countries, various chapters report on analyses of citations from water publications from researchers affiliated with South Africa and SADC countries, which exclude South Africa (referred to in this thesis as SADC-ExSA countries);
- Finally, an analysis of the knowledge produced from Phases I and II of the WARFSA programme is presented.

To address the second objective, a more qualitative analysis was undertaken, and policy and practitioner aspects evident from WARFSA funded projects are presented.

To conclude, based on the objectives of the study, the following hypotheses were investigated, with the outcomes presented in Chapter 13:

1.3.1 The WARFSA programme increased knowledge production.

1.3.2 The WARFSA programme increased the visibility of SADC publications.

1.3.3 The WARFSA programme increased the use of research by policymakers.

1.4 Thesis outline

The thesis is presented in three parts, with **Part A** outlining the researcher project, the literature review and identifying the research methodology. Part A comprises:

- The introduction and statement of the problem in ***Chapter 1*.**
- In ***Chapter 2***, the HERG Payback Framework is presented, which provided a conceptual framework for the study.
- With the HERG Payback Framework in mind, and the objectives of the project, a literature review of the empirical studies on the contribution of water research in the SADC region is presented in ***Chapter 3***, followed by a review of literature on knowledge for policy in ***Chapter 4***.
- ***Chapter 5*** presents the research methodology of the project, given that a mixed methods approach was followed to define quantitative and qualitative datasets.

Part B of the study provides a sector analysis of the SADC water sector with

- ***Chapter 6*** presenting an overview of the institutional landscape of the SADC water sector, describing the local and international institutional overview of the region;
- ***Chapter 7*** provides an overview of the bibliometric analysis of water research knowledge production (scientific impact) in the SADC region between 1980 and 2016, in the context of water research on the African continent and global water research. In addition, the chapter presents the relative effort SADC countries devote to water research.

The following three chapters present results from bibliometric studies on water research publications in the SADC water sector. In each chapter, the bibliometric data are analysed in terms of:

- the **research output** in the SADC region and countries;
- **citation analysis** of research articles;
- the distribution of water research by **journal**; and
- the organisations who are providing financial **support** for the research.

- ***Chapter 8:*** *All SADC countries:* A publication and citation analysis of the knowledge producers (institutional and individual) in the SADC region, the journals where researchers publish, and the institutions that provide financial support for the researchers in order for them to conduct their research are discussed. Chapter 8 further expands on authorship collaboration trends in SADC water research publications.
- ***Chapter 9****: South Africa:* Chapter 9 focusses on the same topics as Chapter 8 but with special reference to South Africa.
- ***Chapter 10****: SADC countries, excluding South Africa:* Chapter 10 reports on the analysis of citation data of knowledge producers (institutional and individual), the

journals where researchers publish and the institutions that provide financial support for the researchers for all countries in SADC, excluding South Africa.

Finally, **Part C** focusses on the knowledge produced and policy and practitioner aspects of the WARFSA programme as a case study:

- ***Chapter 11*** presents knowledge produced from the 78 WARFSA-funded research projects; and
- ***Chapter 12*** addresses policy and practitioner aspects as observed from WARFSA-funded research projects.

The thesis concludes with ***Chapter 13,*** presenting the results and the contribution this study makes. The chapter further provides recommendations to stakeholders of the SADC water sector, and the contribution research capacity development programmes, such as the WARFSA, could make to knowledge production and policy and practitioner aspects as evident from WARFSA-funded research projects.

In addition, Chapter 13 reflects on the Health Economics Research Group (HERG) Payback Framework, and provides recommendations for adaptations to the HERG Payback Framework in order to make it more relevant for research with an ecological dimension.

1.5 Delimitation

This study was limited to the following:

1. In terms of the sector analysis, the study project focussed on programmes, research networks, international organisations and research and innovation units in the SADC region.
2. Bibliometric datasets considered publications categorised as ‘water resources’ in the Web of Science (WoS) citation database.
3. As the study focussed on the WARFSA programme, and although implemented in parallel, knowledge produced by the WaterNet master’s programme and other PhD programmes in the SADC water sector, was not assessed.
4. The conceptual framework used for this study was the HERG Payback Framework (refer to Chapter 2), which presents various impact dimensions against which the benefits from research can be measured. The impact dimensions of the HERG Payback Framework are knowledge, policy, economic and social impacts, and these are discussed in more detail in Chapter 2. This study is limited to the analysis of the knowledge and policy dimensions.

Chapter 2

THE HERG PAYBACK FRAMEWORK: A FRAMEWORK FOR MEASURING THE IMPACT OF SCIENTIFIC RESEARCH

2.1 Introduction

Over the years, various models and frameworks have been developed to analyse the use of research, and have been applied in various studies, with many organisations such as the UKCDR,[2] DFID[3] and IDRC[4] interested in examining the influence of research projects and programmes (UKCDR, 2013). The myriad of frameworks and approaches are highlighted by Banzi, Moja, Pistotti, Facchini and Liberati (2011), where no fewer than ten of the most widespread frameworks and approaches used to assess the impact of health research are highlighted. In a recent article, Coryn et al. (2017) highlight the apparent increase in research on evaluation (RoE) over a decade (i.e. 2005–2014), and further highlighting the vast literature base in the research field. Closer to home, Southern African research institutions such as the Human Sciences Research Council (HSRC) are also considering approaches to evaluate the impact of research (Yu et al., 2016). Greenhalgh, Raftery, Hanney and Glover (2016) reviewed six of the most established approaches and their application in various studies, namely

- the HERG Payback Framework (see Buxton & Hanney, 1996);
- the Research Impact Framework (RIF) (see Raftery, Hanney, Greenhalgh, Glover & Blatch-Jones, 2016);
- the Canadian Academy of Health Sciences (CAHS) Framework (see Canadian Academy of Health Sciences, 2009);
- Societal Impact Assessment and Related Approaches (see Spaapen & Sylvain, 1994);
- the UK Research Excellence Framework (see HEFCE, 2015); and
- the Participatory Research Impact Model (see Cacari-Stone, Wallerstein, Garcia, & Minkler, 2014).

Greenhalgh et al. (2016) further identified other approaches, which could hold future potential, and include electronic databases such as Researchfish® (Researchfish, 2016), realist evaluation (Pawson, 2013; Rycroft-Malone et al., 2015), contribution mapping (Kok & Schuit, 2012), the SPIRIT Action Framework (Redman et al., 2015), and the participatory research impact model (Cacari-Stone, Wallerstein, Garcia & Minkler, 2014; Jagosh et al., 2012).

In terms of the influence of research on policy, Boaz, Fitzpatrick and Shaw (2009) conducted a literature review to examine methods for evaluating the impact of research on policy

[2] The UK Collaborative on Development Sciences (UKCDR) – a group of government departments and research funders
[3] The UK Department of International Development (DFID)
[4] Canadian International Development Research Centre (IDRC)

outcomes. They found that, although a number of frameworks for interpreting research impact were discussed, only a small number of these frameworks were actually used, and usually exclusively used by the same individuals or organisations who had developed them. Figure 2.1 presents the findings of the study, and indicates that economic analysis (normally used as part of a wider analysis), the HERG Payback Model and the RAPID Outcome Assessment dominate research impact assessments in terms of frameworks used.

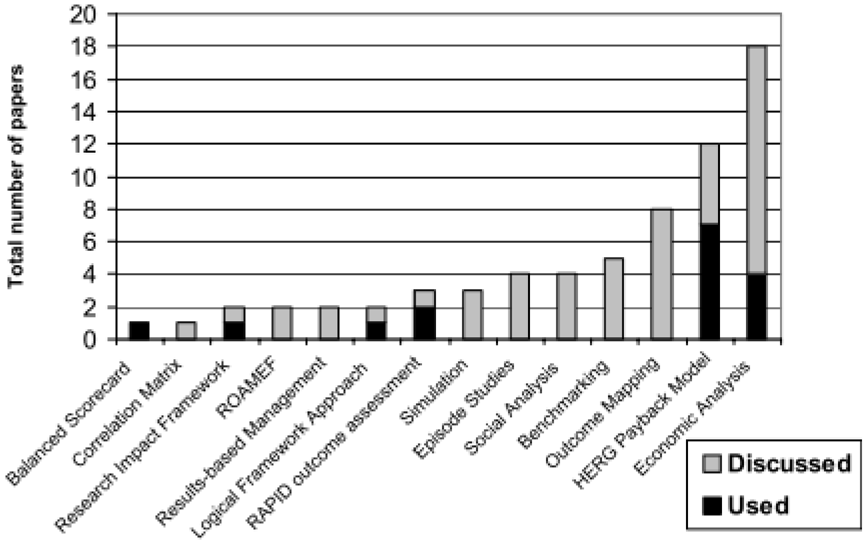

Figure 2.1: Frameworks used for structuring and interpreting data to determine research impact on policy.

Source: Boaz et al. (2009)

Boaz et al. (2009) further identified that most frequently, semi-structured interviews, case studies and documentary analysis are applied to the study of research impact. However, it was found that most studies used more than one research method. Other methods used and/or discussed included bibliometrics, peer panel reviews, surveys, workshops, literature reviews, field visits, user evaluations, telephone interviews, historical tracing, patents or new technologies, network analysis, positive utilisation narratives, impact logs and tracing post-research activity.

Based on the research by Boaz et al. (2009), forward tracking of research is most commonly used, from a piece of research to an outcome such as a policy change as opposed to backward tracking from an outcome to the research. This is supported by Hanney, Buxton, Green, Coulson and Raftery (2007) who argue that forward tracking tends to identify a greater level of impact due in part to the reliance on self-reported data from lead investigators. However, it was further found that some research evaluators tracked research projects in both directions in order to create a high-level account of the relationship between research and policy.

In various studies (such as Boaz et al., 2009; Greenhalgh et al., 2016; Raftery et al., 2016) it was concluded that the HERG Payback Model is the most used framework. In the next section, an overview of the HERG Payback Framework, which formed the theoretical framework for this study, is presented.

2.2 Background and previous use of the Payback Framework

Often referred to as the Payback Framework (see Donovan & Hanney, 2011), the framework was developed in the mid-1990s by the by Health Economics Research Group (HERG) at Brunel University London to evaluate the payback (or benefit) of research in the health systems (Buxton & Hanney, 1996). Since its initial development in the mid-1990s, the HERG Payback Framework has subsequently been used to:

- develop the UK's Economic and Social Research Council (ESRC) analysis of non-academic impact of research further (Cave & Hanney, 1996);
- examine basic and clinical biomedical research further (Wooding, Hanney, Politt, Buxton & Grant, 2011);
- examine its applicability to social sciences (Klautzer, Hanney, Nason, Rubin, Grant & Wooding, 2011);
- in collaboration with other researchers, the Payback Framework has also been applied to assess research influence in various fields, such as diabetes, arthritis and cardiovascular disease in various countries, namely the United Kingdom, the Netherlands, Ireland, Australia and Canada;
- more recently influencing the development of an impact-orientated monitoring framework and set of tools for the monitoring and evaluation of international public health research projects (Guinea *et al.*, 2015); and
- as one of the frameworks to develop the novel conceptual framework, referred to as the framework to assess the impact from translational health research, or FAIT (Searles, Doran, Attia, Knight, Wiggers & Deeming, 2016).

As indicated above, it is thus evident that the HERG Payback Framework has undergone some revision since its development in 1996, to reflect customised perspectives of funders who have commissioned studies using the framework (Donovan & Hanney, 2011).

2.2.1 Elements of the HERG Payback Framework

In essence, the HERG Payback Framework consists of two elements (Donovan & Hanney, 2011), namely a set of five research impact categories (or dimensions) to classify the research paybacks, and a six-stage logical model representing the research process (or research story).

First, the research impact dimensions are presented, followed by the six-stage logical model.

2.2.1.1 Impact dimensions of the HERG Payback Framework

The first element of the original HERG Payback Framework is a set of research impact dimensions, which categorise research outputs and the related benefits of research, as follows (Donovan & Hanney, 2011):

1) *Knowledge and innovation* products – as researchers publish their work in journals, as conference presentations, in books, book chapters and research reports, findings are made public. Often, innovative scientific research results in the development of products and techniques, which could include knowledge products, such as theoretical frameworks, which are often used for further academic research.

   By making use of bibliometric data, research outputs, research growth rates, research collaborations and citation rates can be analysed, and these assist in determining various trends associated with the knowledge production.

2) The *benefits to future research and research use* – when research is undertaken, research results could inform future research and result in better targeting of future research. In addition, research skills of researchers and personnel are continuously developed, which include staff development and educational benefits in the form of qualifications.

3) *Benefits from informing policy and product development* – as will be discussed in detail in Chapter 4, research findings can inform a wide range of policy- or decision-making at any level. Moreover, the ability of research to influence organisational or governmental policy through scientific research has been studied extensively, resulting in various frameworks and models (Caplan, 1979; Jenkins-Smith & Sabatier, 1994; Knott & Wildavsky, 1980; Rich, 1979; Sabatier & Weible, 2007; Weiss, 1979). Such influence on policy could have been the initial objective of a research project, or it might have occurred inadvertently as a consequence of the research project. Policy interventions are often facilitated through policy briefs or guidelines, or by an individual being appointed in an influential position to affect such influence (Lindquist, 1990; 2001; Rich, 1990). By making their research more relevant to political and executive decision-

makers, knowledge producers could contribute towards such policy interventions through scientific research.

Typical outputs resulting from this dimension include national policies, local guidelines and policies developed by those responsible for training, education and inspection. Training packages, curricula and audit and evaluation criteria are examples of this (National Institutes of Health, 2000). Other outputs could be policies about media campaigns (Hanney, Grant, Wooding & Buxton, 2004), and adoption of policies and products (Buxton & Hanney, 1996) that would contribute towards the benefits of this dimension.

4) *Health and health sector benefits* – since the 1990s, there has been a clear trend not only to measure influence of research on academia and scientific knowledge, but also an expectation that evidence of the value of science to society need to be demonstrated (Martin, 2011). Such value often leads to a behavioural change as a consequence of people's interaction in a research project (Spaapen, Van Drooge, Propp, Van der Meulen, Shinn & Marcovich, 2011). Moreover, since the HERG Payback Framework was originally developed for the health sector, many benefits, such as improved health, cost reduction in delivery of existing services, qualitative improvements in the process of delivery, improved equity in service delivery, currently identified in literature relate to the specific sector.

   The benefits of research on society can be measured in various ways, and can be "much harder to assess than scientific research" (Bornmann 2013:230), with various advantages and disadvantages associated with different methods. Examples would include case study methods, which, even though they record the complexity of societal benefit, can be very expensive, and require a uniform approach with the same indicators in order to assess the benefit of different institutions. Other methods are productive interactions through stakeholder interviews, which include the researchers and beneficiaries as demonstrated by the development of social impact assessment methods through productive Interactions (SIAMPI) (Spaapen & Van Drooge, 2011; Spaapen et al., 2011).

5) *Benefits derived within the broader economy* – the HERG Payback Framework provides a research impact dimension addressing the benefits, which could potentially be derived within the broader economy. Such benefits could result from the commercial exploitation of innovations arising from R&D. It is however not just the commercial exploitation of innovations that could have benefits for the broader economy, with better health systems leading to increases in employment, working days and profits, resulting in the increased manufacture and sales of products and services (Rosenberg, 2002).

Further benefits to the national economy could be an increase in exports and/or import substitution (Gadelha, 2000; Hale & Towse, 1995).

As diverse as these impact dimension are, it is important to note that it should not necessarily be the objective of research projects to influence all research impact dimensions, and that is perfectly appropriate for a project, for example, to generate knowledge only (Buxton, 2011).

The second element of the HERG Payback Framework is a logic model, which is discussed in more detail in the next subsection.

2.2.1.2 The logic model of the HERG Payback Framework

The second element of the Payback Framework, the logic model, consists of seven stages of research, and facilitates the analysis of the research process, from inception in Stage 0, through to the final outcomes in Stage 6 (refer to Figure 2.2). The stages include the topic or issue identification (Stage 0) when the research project is initiated, followed by inputs to research (Stage 1); the research process (Stage 2); primary outputs from research (Stage 3); secondary outputs from research (Stage 4); adoption by practitioners and public (Stage 5); and, finally, research outcomes (Stage 6).

The logic model further indicates two interfaces between the research system and the wider political, professional and economic environment, with the first (project specification and selection) between Stages 0 and 1 (the topic identification and inputs to research) and the second (dissemination) between Stages 3 and 4, following the primary outputs from the research and the secondary outputs being policymaking and product development. While it is not completely possible to identify the dimensions of benefits to specific stages of the logic model, it is possible to identify broad correlations (Donovan & Hanney, 2011). For example, ‘knowledge and ‘benefits to future research and research use’ are generally the primary outputs from research (Stage 3), with ‘benefits from informing policy and product development’ typically relating to secondary outputs (Stage 4), and ‘health and health sector benefits’ and ‘broader economic benefits’ generally being identified as final outcomes in Stage 6.

Each of the seven stages and interfaces of the logical model are discussed in more detail.

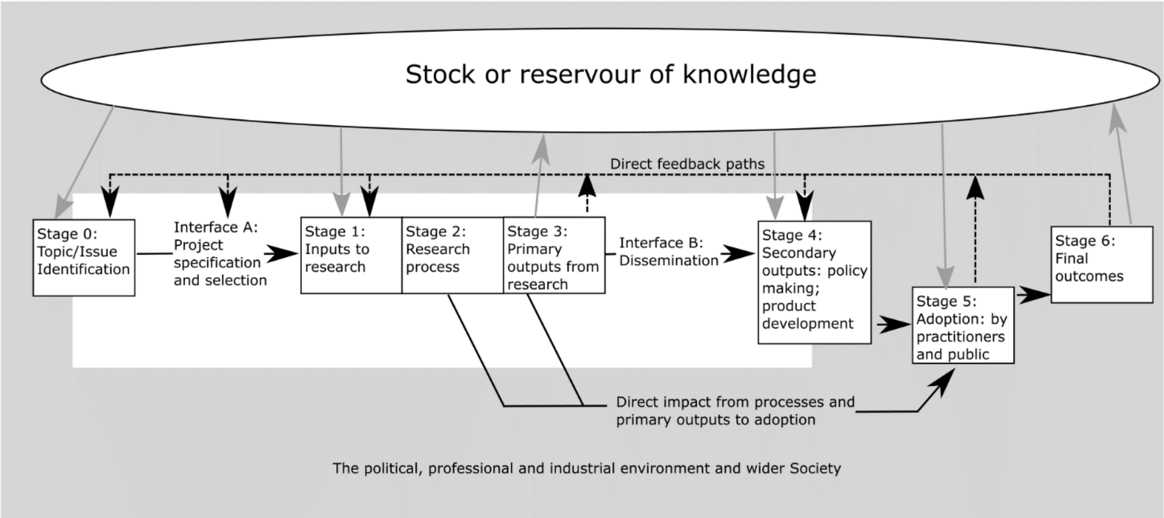

Figure 2.2: The logic model of the Payback Framework

Source: Hanney et al. (2004)

- ***The early stages of the research process Stage 0***

  Initially, a topic or issue is identified though a review of the scholarship (Stage 0), and is undertaken with inputs from the reservoir of knowledge and inputs from the political, professional, industrial environment and the wider society. Here, with inputs from the scientific body of knowledge and other stakeholders, the research question is framed and defined, often with various assumptions framing the research question, which could potentially be mapped through impact pathway mapping and logic models (Shaw & Bell, 2010). Environmental scanning provides the motivation for the research, which could then be translated into a research proposal for potential funding.

- ***Conducting research moving from Stage 0 to Stage 3***

  Once the research question has been identified and typically captured in a research proposal (Bordens & Abbott, 2002; Creswell, 2014), the research process moves into the first of two interfaces within the research process. Interface A, between Stages 0 and 1, provides the opportunity for researchers to draft the project specifications, where a research proposal is often submitted for funding. These could be in response to a call presented by local or international funding agencies to subsidise a research project and where projects are evaluated and selected for commissioning. Once approved, the research passes on to Stage 1, where continuous inputs are gained from the scientific body of knowledge and the larger stakeholder group while research is conducted in the research process in Stage 2. Eventually, primary research is produced in Stage 3. The research process could take a number of years depending on the type of research, but typically post-graduate qualifications, research publications in peer-reviewed journals, knowledge models and frameworks, patents and scientific knowledge products developed by the researchers result from the research over a number of years.

- ***Research dissemination for secondary outputs and practitioner applications moving from Stage 3 to Stage 5***

  The second of the two interfaces occurs between Stages 3 and 4 after the primary outputs from the research had been produced and disseminated from where secondary outputs are produced in Stage 4. At this Stage, decisions also need to be taken by the science communication practitioner on the modalities of science communication, such as science promotion and science education, and the intended effect of the science communication process (Van der Sanden & Meijman, 2012). Only after these knowledge products had been developed, are they ‘packaged’ as secondary outputs, such as policy briefs, policy and legislative documents, information guidelines, and outputs aimed at the ‘non-academic’ audience (Stage 4). Moreover, The HERG Payback Framework suggests that the research process and primary outputs in stages 2 and 3 could directly benefit practitioners and the public, which leads to the adoption of research findings (Stage 5) this without the intentional dissemination or development of secondary outputs.

- ***The interface between the body of knowledge and external stakeholders in the research process***

  Throughout the entire research process, from Stage 0 when the research topic is identified to when final outcomes materialise in Stage 6, inputs are gained and feedback is provided between the scientific body of knowledge and broader stakeholders. In the early stages of the research process (when the research topic is identified and the initial stages of input into the research take place), the input is gained from the reservoir of knowledge, feeding into the research process. The latter is repeated later in the research process, when secondary outputs are generated (Stage 4) and when practitioners’ applications are developed (Stage 5). Moreover, the HERG Payback Framework acknowledge inputs from the political, professional and industrial environment and the wider society when the research topic is identified (Stage 0) and when secondary outputs are developed and research outputs are adopted, which leads to eventual outcomes in stages 5 and 6.

- ***Feedback loops***

  In order to indicate that the logic model is not a linear process (Donovan & Hanney, 2011), various feedback loops are evident. Such feedback loops are evident where knowledge is fed from primary outputs of the research (Stage 3), the practitioners’ applications (Stage 5) and from the final outcomes (Stage 6) back into the research process, for uptake in the various stages of the research process. The feedback loop extends to where secondary outputs are developed in Stage 4, inputs into the research occur (Stage 1) and also in

Stage 0, when the topic or issue of research is identified. Feedback could include results from practitioner applications and the public at large, or feedback from research articles and academic outputs.

The logic model further indicates how information is fed from the stock (or reservoir) of knowledge

- when the research topic is identified in Stage 0;
- when inputs into the research are obtained in Stage 1;
- when secondary outputs, such as policy briefs and product development, take place in Stage 4; and
- when practitioners and the public adopt research findings in Stage 5.

In addition, the research process also feeds back into the reservoir of knowledge at Stage 3 when primary outputs from the research are produced, and the final outcomes of the research become evident in Stage 6. This can be over quite a length of time.

As established so far, the HERG Payback Framework has been identified as the most widely used framework in determining research impact (Boaz et al., 2009; Greenhalgh & Fahy, 2015; Milat, Bauman & Redman, 2015). The HERG Payback Framework has further been adapted and applied beyond healthcare to demonstrate that research investments deliver payback of value to society (Henshall, 2011), arts and humanities research (Levitt, Celia, Diepeveen, Chonaill, Rabinovich & Tiessen, 2010), social sciences (Klautzer et al., 2011) and more recently, the development of an impact-orientated monitoring methodology for the evaluation of international public health research projects (Guinea et al., 2015). Given its wide use, it can be expected that the HERG Payback Framework has not been without criticism, as discussed in the next section.

2.2.2 Criticism of the HERG Payback Framework

Although it is acknowledged that the HERG Payback Framework is intuitive and that it provides results of use to policymakers, funders and the general community, it is suggested that substantial resources are required to implement the HERG Payback Framework (Searles et al., 2016). This is due to the mixed-method approach, where a combination of researcher interviews, document analysis and validation work is required. This has led to the modification of the Payback Framework to reduce the resources required to assess the influence of the research (European Commission, 2013; Greenhalgh et al., 2016). In addition, Greenhalgh et al. (2016) argue that the Payback Framework is generally focussed on a specific funded project, and thus presents limitations in that the Payback Framework is less able to identify impacts related to a research group, which attracts funding from other funding sources. However, Martin Buxton who, along with Stephen Hanney, originally presented in the HERG

Payback Framework in the mid-1990s, acknowledges that it has always been emphasised that within the Payback Framework, “any impact is the product of the whole R&D system and not exclusively produced by the original researchers themselves” (Buxton, 2011:260).

Further, despite its name, the researchers have indicated that the Payback Framework does not measure impact in monetary terms (Greenhalgh et al., 2016), even though this might be slightly misguided, as economic benefits is one of the impact dimensions presented in the Payback Framework (see for example Buxton, Hanney & Jones [2004] and Nason, Janta, Hastings & Hanney [2008]).

Further criticism is more general in nature, and aimed at the use of logic models, which is a major element in the Payback Framework. Here, criticism has been raised that in general, the linear nature of logic models could oversimplify complex pathways or links between inputs, outputs and outcomes, throughout the lifecycle of research projects, and is it widely recognised that not all research impact links can be predicted and quantified (Greenhalgh & Fahy, 2015; Raftery, Hanney, Greenhalgh, Glover & Blatch-Jones, 2016:49). Some of the challenges related to the use of logic models, have been highlighted in studies such as by Boaz et al. (2009), Bornmann (2013), Bozeman and Rogers (2002), Briggle (2014), Frank and Nason (2009), Kok and Schuit (2012), Meagher, Lyall and Nutley (2008), Martin (2011), Penfield, Baker, Scoble and Wykes (2014), Upton, Vallance and Goddard (2014). After a recent study, Raftery et al. (2016) summarised this criticism as follows:

- In certain circumstances, especially when the context is complex with multiple variables that are rapidly changing, the assumption of a *linear causality* could be problematic. Frameworks such as the Payback Framework do provide a degree of ‘permeability’ between research, practice and policy, but critics argue that is problematic to assume that with careful measurement of input, process and context variables, meaningful conclusions about the links between a research programme and resulting impact can be drawn. This further relate to predicting comparable impact in the future.
- Critics argue that logic models are *disciplinary biased* towards ‘hard’ research such as trials, over ‘soft’ research such as developmental and research projects that make use of qualitative research methods. In an apparent ‘quest to measure the measurable in an ‘objective’ way’, logic models could be compromised and overlook unmeasurable elements in a research discipline.
- Critics further argue that an overly rigid logic model could miss research impact when the timescales are at the *temporal extremes*, with the ability to quantify and establish attribution reduces with the number of steps from outputs (thus time) (Boaz et al., 2009). Moreover, impact pathways often follow through multiple reservoirs and

'untraceable times and places' (Kok & Schuit, 2012), thus contributing towards challenges relating to causality.

- In addition, researchers have raised questions relating to *attribution* – are the research output really the key driver for the eventual impact? (Boaz et al., 2009; Hargreaves, 2009; Molas-Gallart, Salter, Patel, Scott & Duran, 2002; Molas-Gallart & Tang, 2011). In some cases, studies have preferred to use language that focusses on influence of research rather than impact (Boaz et al., 2009).

- Moreover, critics have questions related to *additionality* – how does the contribution of the research compare to that of other drivers (Davies, Nutley & Walter, 2005), and would the same benefit be achieved without the research programme (Klautzer et al., 2011). Researchers have raised further questions related to opportunity cost, and whether a greater benefit to society could have been achieved had the research budget been spent differently.

- According to Raftery et al. (2016), critics argue that logic models could be subject to *excessive abstraction*, and that they could create an impression of rigour through 'hard' analytics. The challenge, it is argued, is that real-world knowledge use is more complex in how it is interpreted and valued by society, and could logic models present a disconnect to real-world use of knowledge.

- As indicated earlier, the costs associated with a multimethod case study approach might be *impractical* in some cases, while reducing such approaches to 'tick-box surveys' or 'standardised surveys' could produce results that are not valid.

- Finally, critics argue that *ethical issues* could arise where the benefit of research might be determined to be significant, morally questionable. For example, where research distorts rather than informs decision-making and where research impact is achieved at the expense of the environment. It is further argued that an increase of economic models could mask questions relating to 'what kind of research is morally right', where such questions are downplayed in favour of innovation and economic growth.

From this section, it is thus evident that the HERG Payback Framework, even with its suggested limitations, has been applied extensively to measure the benefit of research. Moreover, even considering the limitations, as a conceptual framework, the HERG Payback Framework was chosen for the study, as –

- it provides an adequate framework to analyse the knowledge and policy aspects of water research in the SADC region, and how these relate to the WARFSA programme; and

- the logic model of the Framework adequately presents the stages of the WARFSA programme, specifically as they relate to the historical implementation time frames of the WARFSA.

2.3 The HERG Payback Framework and the research objectives

When considering the elements of the HERG Payback Framework and the focus of this study on the scientific and policy impact dimensions aspects arising from WARFSA-funded research, our focus was on specific stages of the HERG Payback Framework only (refer to Figure 2.3). The first focus is on Stage 3, when primary outputs from research are produced, and related to knowledge production that is fed into the stock or reservoir of knowledge and into the feedback paths of the HERG Payback Framework. In addition, the focus of this study was on Interface B, where primary outputs are 're-packaged' and disseminated, which result in secondary outputs for policymaking and product development in Stage 4. Such secondary outputs could result in the adoption of research in Stage 5. In addition, it is acknowledged that the research process and primary outputs from research can influence the adoption of research.

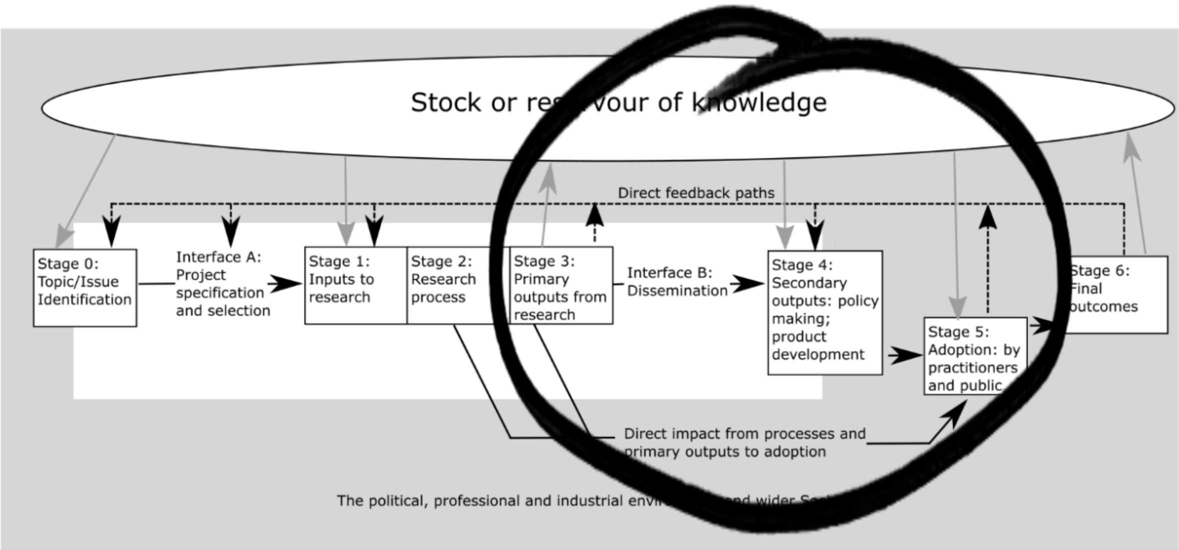

Figure 2.3: The HERG Payback Framework and the objectives of this study

Source: Adapted from Hanney et al. (2004)

Against this background, a review of the literature which is presented in the next two chapters, consists of two aspects:

1) empirical studies, which have analysed the scientific contribution of water research in the SADC region, and
2) the theoretical basis of knowledge for policy.

These two aspects guided the analysis of knowledge produced in the SADC water sector (Chapters 7 to 10) and WARFSA projects (Chapter 11), and in addition, the analysis of policy aspects relating to WARFSA-funded research, as presented in Chapter 12.

Chapter 3

REVIEW OF STUDIES ON WATER RESEARCH IN THE SADC REGION

3.1 Introduction

In the previous chapter, it was reported why the HERG Payback Framework was identified as a suitable framework for this study, given the scope of the study on the contribution of the WARFSA to knowledge production and policy in the SADC water sector. It was further established that a literature review of two aspects needed to be conducted, with the first being a review of previous empirical studies on water research in the SADC region, and secondly, a review of prominent knowledge utilisation literature, as it relates to knowledge for policy. The aim of this chapter is to focus on the first aspect, namely a review of past empirical studies on water research in the SADC region.

3.2 Review of empirical studies on the scientific contribution of water research in the SADC region

Water research is undertaken within the broader science research context of the African continent. In general, there have not been many bibliometric studies aimed at analysing science production in Africa (Confraria & Godinho, 2014; Tijssen, 2007). Where studies have been undertaken, some have given a general overview of science production (Adams, King & Hook, 2010; Narváez-Berthelemot, Russell, Arvanitis, Waast & Gaillard, 2002; New Partnership for Africa's Development [NEPAD], 2010; 2014; UNESCO, 2015; World Bank Group, 2014). In addition, there have been studies focussing on topics such as

- research collaboration trends on the African continent (Adams, Gurney, Hook & Leydesdorff, 2014; Confraria & Godinho, 2014; Onyancha & Maluleka, 2011; Pouris & Ho, 2013; Pouris & Pouris, 2009; Toivanen & Ponomariov, 2011); and
- studies with a focus on specific regions or specific countries in:
    - the Arab countries (Waast & Rossi, 2010);
    - West Africa (Mêgnigbêto, 2013a; 2013b; Owusu-Nimo & Boshoff, 2017);
    - Central Africa (Boshoff, 2009); and
    - Southern and South Africa (Boshoff, 2010a; Mouton, Boshoff, Waal, Esau & Van Niekerk, 2008; Pouris, 2010; 2017; Sooryamoorthy, 2009).

Often, these studies give insight into the different research areas that are being researched, for example showing that there is a general emphasis on the medical science, life science and natural sciences on the Africa continent (Boshoff, 2010a; Pouris & Ho, 2013). Moreover, some studies have highlighted the association some research had with the colonial past of a country, where agricultural sciences are often covered by Anglophone countries, and medical sciences by Francophone countries (Arvanitis, Waast & Gaillard, 2000). In Southern Africa, research in agriculture and animal sciences is also prominent (Pouris, 2010).

Given the focus of this study on water research, a recent study by Wambu and Ho (2016) was undertaken as *a bibliometric analysis of drinking water research in Africa* for publications between 1991 and 2013. In the study, various aspects relating to water research output were identified, for example, that the co-publishing of articles was increasing along with an increase in the bibliographic sources per article. In addition, the top subject areas were

- water resources (27%);
- environmental science (24%);
- environmental and occupational public health (12%);
- toxicology (8,2%); and
- environmental engineering (7,7%) to name only the top five subject areas.

The study further found that South African universities and research institutions dominate the research output (28,3%), followed by

- Egypt (21,7%);
- Tunisia (15,2%);
- Nigeria (13%); and
- other institutions from Botswana, Ethiopia, Ghana, Kenya, Malawi, Morocco, Sudan, Tanzania, Uganda and Zimbabwe.

In terms of research collaboration, the study found that 48,9% of the drinking water research was published by African institutions, in collaboration with institutions from beyond Africa, predominantly in

- Europe (56%);
- North America (20%);
- Far East (12%);
- Middle East (9,1%);
- Australia (2,3%); and
- South America (1,3%).

Wambu and Ho (2016) further found that drinking water research was further increasingly cited since the turn of the century, with the highest visibility and scientific impact of articles associated with review articles and internationally collaborative articles.

In terms of water research, and specifically in the Southern Africa region (SADC), few bibliometric studies have been undertaken, with studies mainly focussing on South Africa. Results from the existing water research bibliometric studies in the SADC region, are presented in the next section, followed by detail on water-related studies focussing on South Africa.

3.2.1 SADC regional water research bibliometric studies

From a SADC regional perspective, only one bibliometric study directly relating to the water sector could be identified, namely the article by Van der Zaag (2007). The article reports on an analysis of the qualitative and quantitative contribution of the WaterNet/WARFSA/GWP SA symposium[5] papers, and also the WaterNet/WARFSA/GWP SA symposium papers published in five special issues (2002 to 2006) of the scientific journal, *Physics and Chemistry of the Earth (PCE)*, which was linked to the symposium. In the study, Van der Zaag (2007:974) shows that the special issues of PCE, which contained the best articles emanating from the symposia, significantly increased the number of articles published in the African water sector. In addition, these articles showed a high scientific impact, with the articles being cited 1,69 times over a period between 2002 to 2006 (with only 11% of the papers not being cited at all), whereas the total citation average was 1,49. Moreover, articles were cited 1,42 times on average during 2002 to 2006. However, Van der Zaag indicates that there was a decreasing trend in the impact factor of the articles, which should be monitored over time (something which has not been reported on in subsequent years). Further, articles relating to themes 'Water and society' and 'Water resource management' were cited most frequently, possibly finding a 'home' in the PCE journal. Van der Zaag (2007) concludes that the number of articles published in the five special issues of PCE was significant when compared to all water-related publications in Africa, indicating the positive influence the WaterNet/WARFSA/GWP SA symposia, WARFSA and GWP SA (Global Water Partnership – Southern Africa) initiatives had in contributing to publications in the African water sector (at the time). Finally, Van der Zaag concludes that the quality of work presented at the symposia at the time varied, and that the symposia did indeed have a positive influence on knowledge production in the SADC water sector.

3.2.2 South African water research bibliometric studies

In South Africa, Pouris (2013) undertook a study on the state of water research and development in South Africa (analysing bibliometric data for the period 1981 to 2010), and also a state of water research in South Africa (Pouris, 2015), spanning a period between 1981 and 2014. Both studies (Pouris, 2013; 2015) were conducted for the WRC with Anastassios Pouris as the sole author, with the 2013 study resulting in the publication of an article by Jacobs, Pouris and Naido (2014).

In terms of funding spent on water-resource research, Pouris (2015) indicates that water-related R&D spending amounted to R240 million in 2014, an increase from R50 million in 2000 (Figure 3.1). At first glance, such spending seems significant; however, it only amounted to

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[5] The WaterNet/WARFSA/GPW-SA symposium has been held annually since 2000 in the SADC region.

0,0069% of the gross domestic product (GDP) in 2014 (Pouris, 2015:5). The study further indicated that the WRC was funding 65% of all water-related research in South Africa in 2014, followed by the Council for Scientific and Industrial Research (CSIR) (16%), Mintek (9%) the National Research Foundation (NRF) with 8%, and the Agricultural Research Council (ARC), 2%.

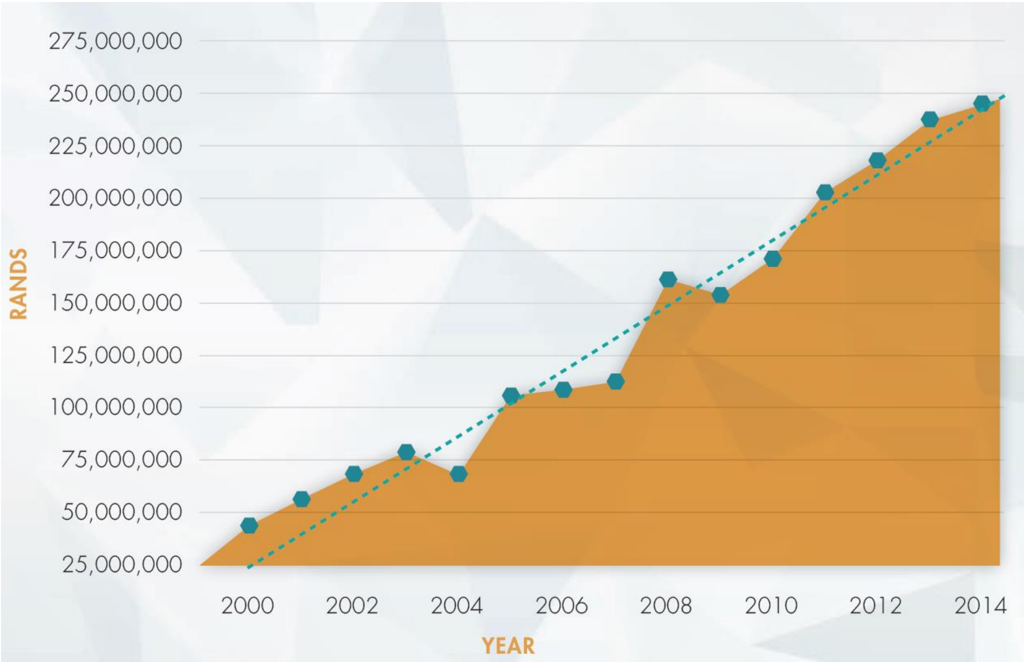


Figure 3.1: Funding spent on water R&D (2000–2014)

Source: Pouris (2015:4)

The studies (Pouris, 2013; 2015) indicated that South Africa has experienced a steady increase in water research publications since 1981 to 2010, from approximately 60 publications per year in 1981, to just below 180 publications per year in 2009 (Pouris, 2013:28), and 200 per year in 2014 (Pouris, 2015:1516). It is not clear which document types, i.e. peer-reviewed articles, conference proceedings, patents, books and book chapters Pouris used for the studies, but it is argued that all document types were used as captured within the Clarivate Analytics SCI databases (Science Citation Index Expanded, Social Sciences Citation Index and Arts and Humanities Citation Index). Moreover, in terms of research output as a percentage of world share (Table 3.2), South Africa's world share of water research publications has declined from 3,5% (in 1982) to 1,69% in 2010, with a general stabilisation of between 1,4% and 1,8% between 2002 and 2010 (Pouris, 2013:29). Most recently (in 2014), it has been recorded at 1,5% of the world share (Pouris, 2015:16). Pouris (2015:19) points out that South Africa was ranked 19th globally in the field of water research publications over the period 2015–2014, being the only African country being ranked in the top 20, and ranked 33rd in terms of total publications in all fields. Pouris (2015) however does not indicate which specific year this ranking was made, but it is assumed that it was around the publication of the report in 2015, and remain indicative of the ranking at the time of the report.

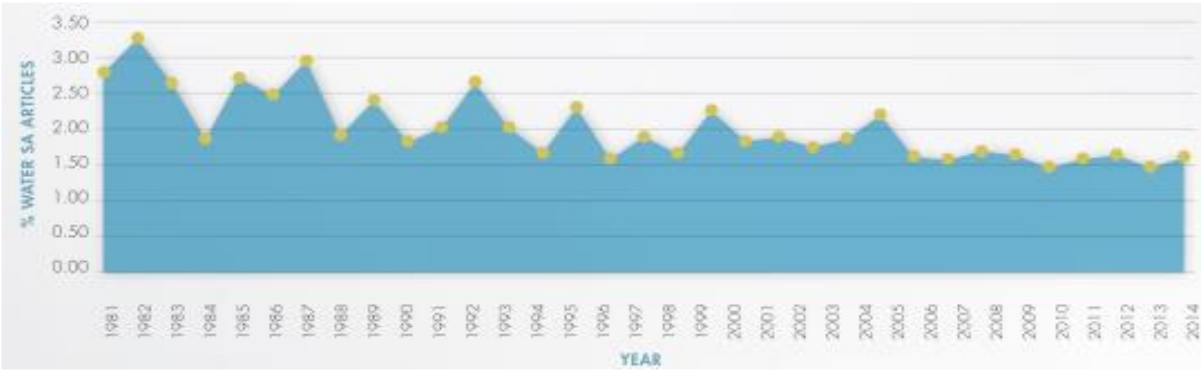


Figure 3.2: South African world share of water research articles

Source: (Pouris, 2015:15)

Pouris (2013:31) further presents the character of South African water research publications for the period 1999 to 2012, which indicates that 2 323 water research publications were produced in South Africa for this period. Moreover, during this period, a large portion of the publications was in the field of environmental sciences and environmental engineering, with relatively few publications in the field of soil sciences, economics, management and energy, reflecting the interdisciplinary nature of water research (Pouris, 2013:31).

Further, Pouris (2013:32) found that for the period 1999 to 2010, the University of Pretoria has been the most prolific research institution for water research in South Africa, followed by the University of Cape Town, the CSIR, University of KwaZulu-Natal and the University of the Witwatersrand. Pouris (2015:16), did however found that for the period 20052014, the University of KwaZulu-Natal published the most articles (246), followed by the University of Pretoria (166), the University of Johannesburg (137), and then the CSIR (131). The institutional focus of such water research publications at the institutions also reveals that the University of Pretoria, University of Cape Town and the CSIR focussed on Environmental Sciences and Engineering Environment, whereas Multidisciplinary Geosciences was highlighted at the University of KwaZulu-Natal and the University of the Witwatersrand (Pouris, 2013:3435) again, highlighting the interdisciplinary nature of water research. Moreover, the University of Cape Town produced the most prolific authors in water research publications (G.A. Ekama and M.C. Wentzel), followed by C.A. Buckley at the University of KwaZulu-Natal, D.A. Hughes (University of Rhodes) and T.E. Cloete at the and University of Pretoria. It was also found that, where researchers did acknowledge funders of their research, the NRF and WRC were acknowledged most often (Pouris, 2013:3236).

Researchers also collaborate with other researchers globally, which results in collaborative publications, patents and post-graduate students. Pouris (2015:19) found that 35% of water-related publications produced by South African researchers had international co-authors in 2014, mostly researchers from the United States, the United Kingdom, Australia and the Netherlands. Moreover, such research collaboration falls within a trend where international collaboration has steadily increased since 2010, both in terms of water-related research and in terms of all publications.

Both studies (Pouris, 2013; 2015) further assessed patent data obtained from the United States Patent and Trademark Office (USPTO), which is presented in Table 3.1. Even though the data as presented in Table 3.1 overlap, Pouris (2015:8) reported that 46 water related patents were granted by the USPTO to South African inventors between 2000 to 2014, which translates into 2,32% of all South African patents for the period 2000 to 2010 and 3,39% of all patents during 20052014 (see Pouris, 2013; 2015). This ratio is consistently higher than most countries as presented in Table 3.1, with notably Brazil experiencing a significant increase in the ratio of patents registered as a portion of overall patents registered.

Table 3.1: Water patents as a % of patents granted (USPTO)

	2000–2010			2005–2014		
Countries	**Water patents**	**Total patents**	**Ratio**	**Water patents**	**Total patents**	**Ratio**
Brazil	28	1 207	2,32%	55	1 332	4,13%
South Africa	42	1 134	3,70%	34	1 004	3,39%
Russia	56	2 141	2,62%	56	2 198	2,55%
Australia	180	12 055	1,49%	181	12 837	1,41%
Canada	573	38 941	1,47%	523	39 020	1,34%
China	112	8 675	1,29%	270	21 111	1,28%
India	66	5 085	1,30%	111	9 171	1,21%
United Kingdom	397	29 097	1,36%	397	35 877	1,11%
Japan	2 469	384 738	0,64%	2 445	363 233	0,67%
Finland	61	9 293	0,66%	54	8 587	0,63%

Source: Pouris (2013; 2015)

In addition to the 2013 study, Pouris (2015) presents data relating to human resources in water R&D in South Africa, and specifically in terms of master's and PhD theses awarded, as it is important to attract, develop and retain research talent for Science and Technology (S&T), and also important to meet science advance for decision-making (Figure 3.3). From Figure 3.3, it is evident that 1 654 water related master's theses had been accepted since 2000, while 315 water related PhD theses had been accepted, with the highest number of master's theses accepted in 2010, and 32 PhD theses accepted in 2002. General trends from Figure 3.3 follow highs in the early 2000s and late 2010s for both master's and PhD theses, with a sharp decline in master's theses, from the high of 171 in 2010, to a lowest number master's theses (55) in 2014 (Pouris, 2015:11).

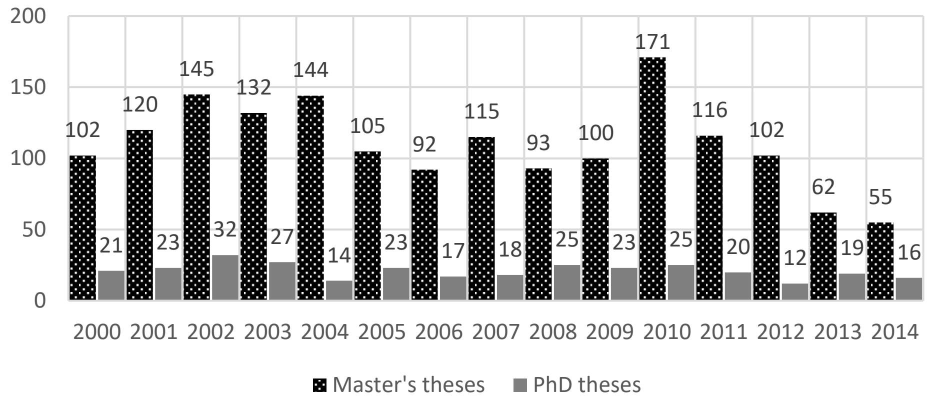


Figure 3.3: Number of South African water-related master's and PhD theses awarded per year (2000–2014)

Source: Pouris (2015)

The top universities accepting water-related master's and PhD theses between 2000 and 2014 are presented in Table 3.2, which indicates that the University of Witwatersrand produced the biggest combined total (210), followed by Stellenbosch University (204) and the University of Pretoria (177). Unfortunately, the numbers of master's theses for the University of Cape Town, Rhodes University, the University of the Free State and the University of KwaZulu-Natal were not provided in the report.

Table 3.2: Number of water-related master's and PhD theses accepted per university (2000–2014)

Institution	PhDs	Master's	Total
University of the Witwatersrand	30	180	210
Stellenbosch University	23	181	204
University of Pretoria	42	135	177
North-West University	13	147	160
University of the Western Cape	26	123	149
University of Cape Town	37	*	
Rhodes University	36	*	
University of the Free State	32	*	
University of KwaZulu-Natal	11	*	

* Not indicated in the report

Source: Pouris (2015:1011)

The WRC has also contributed towards human capacity development, and even though the WRC does not provide bursaries, researchers are encouraged to involve post-graduate students in the research projects funded through the WRC. Pouris (2015:1213) indicate that, on average, 500 students have been supported annually between 2007 and 2014.

Another study was conducted by Siebrits and Winter (2013), with the aim to analyse water research paradigm shifts in South Africa, especially in relation to the pre- and post-political reform period in the mid-1990s a study undertaken for the WRC. Scientometric results from the study concluded that in total, 6 007 water-related publications were produced between 1977 and 2011, of which 29,30% were WRC reports, and 30,45% peer-reviewed journal articles published in *Water SA* (Figure 3.4). The results reflect a notable increase in other journal articles since the early 1990s, with a rise in *Water SA* articles and a marked increase in WRC research reports.

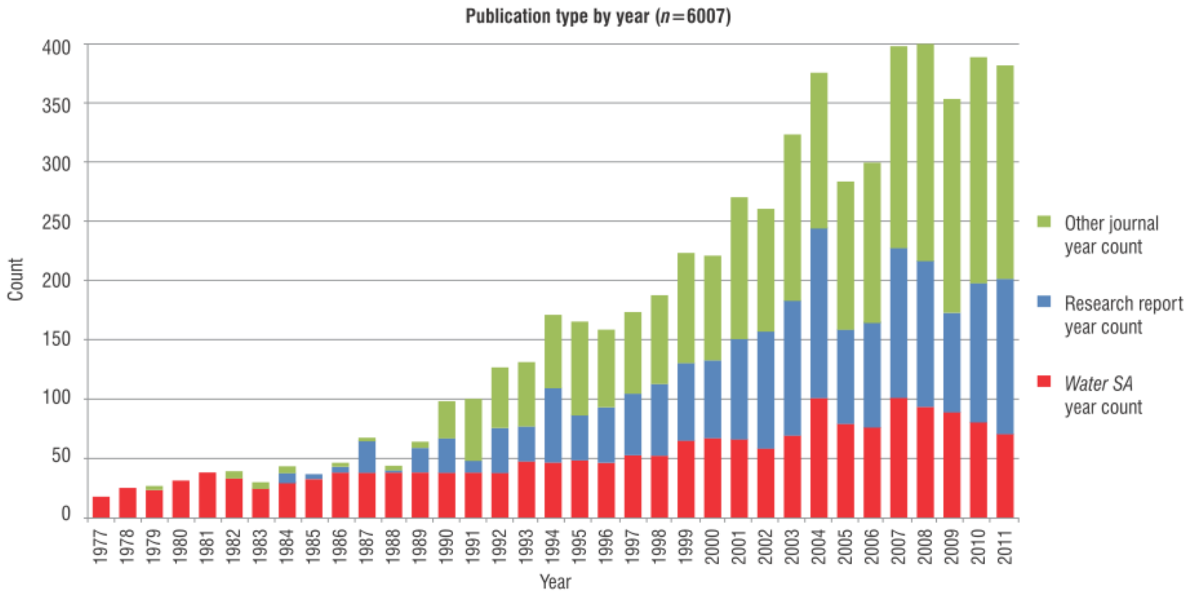


Figure 3.4: Publication type by year of South African publications

Source: Siebrits, Winter and Jacobs (2014:3)

By making use of scientometric mapping techniques, shifts in the focus of research topics were identified by making use of the publication history of water-related publications between 1977 and 2011. Results from the study (Siebrits et al., 2014) indicate that research predominantly focussed on topics related to management, development, models, quality and system treatment (Siebrits et al., 2014:8), with a focus on technical matters dominant in the earlier records and other paradigms, such as allocative efficiency, uncertainty, and risk present to a lesser extent. Moreover, two major paradigms were identified, with the first identified from 1977 to 1991, emphasising research aimed at securing water supply and a better understanding of natural systems, dominated by engineering and laboratory-related disciplines. In the second paradigm (from 1992 to 2001), a transition is observed highlighting quality constraints and research fields relating to management and planning. This second paradigm is further associated with the regime change in South Africa and a period of major transition, growing environmentalism and an increase in civil society activism. Disciplines, such as the planning and modelling of catchments, are evident in research fields. The study (Siebrits et al., 2014) identified the 40 top priority research questions through stakeholder engagements, which included questions such as related to management, treatment, quality, supply, wastewater, agriculture, pollution and governance. These questions were categorised according to short-, medium- and long-term research questions, which revealed that 78% of research questions aimed at addressing short- and (mostly) medium-term questions, dealing with service delivery, sanitation, access to water, pricing and water quality. These questions were also in line with the transition paradigm as observed through the scientometric analysis (Siebrits et al., 2014).

The study by Siebrits and Winter (2013) resulted in the publication of a research article in the *South African Journal of Science* and an article published in *WaterSA* (Siebrits et al., 2014).

In 2014, the WRC commissioned a reflection on South Africa's 20-year journey in water and sanitation research (Jacobs, Du Plessis, Trollip & Van Vuuren, 2014). In this book, the WRC highlights some of the successes achieved through research and related activities, conducted by the WRC. In the publication, Jacobs, Du Plessis, Trollip and Van Vuuren, (2014) highlight the following:

- achievements related to informing policy and decision-making;
- the research journey of transformation;
- water research in transforming the South African society; and
- empowering communities; and
- new products and services for the benefit of economic development.

The publication further highlights successes related to sustainable development solutions and human capital development, concluding with activities which the WRC aims to conduct in the near future, such as the State of Water R&D Project (see Pouris, 2015), which consistently reports on, evaluates and critically appraises the status of R&D trends in the South African water sector.

From this section, it is evident that previous bibliometric studies in the SADC region extensively focussed on publications from researchers affiliated with South African universities and research institutions.

3.3 Conclusion

This chapter showed that few water research bibliometric studies have been undertaken in the SADC region, with a number of studies mainly focussing on South Africa. In the case of the SADC regional study (Van der Zaag, 2007), the study mainly focussed on the citation impact of articles produced during the annual WaterNet/WARFSA/GWP SA between 2002 and 2006, and published in five special issues (2002 to 2006) of the scientific journal, *Physics and Chemistry of the Earth (PCE)*, which was linked to the symposium. Aspects considered included the number of papers and the citation impact of the papers as these relate to knowledge production in the African context, and themes as they relate to the annual WaterNet/WARFSA/GWP SA symposia during the time. South African bibliometric studies mainly focussed on the number of publications, 'prolific' authors and institutions producing water research in South Africa, mostly after 2000. Studies further provide information on the funding spent on water research in South Africa, and the number of master's and PhD qualifications produced, which are often not very clear on the methodologies used to analyse datasets. Studies further highlight innovation products, such as patents registered with the USPTO, again for the period after 2000. In other cases, studies highlight paradigms of focus areas of the water research in South Africa.

Although these studies provide a significant contribution to our understanding of water research in (specifically) South Africa, our understanding of the scientific contribution in water research in the larger SADC region is clearly limited. Aspects which could be investigated further, include the institutional landscape in the SADC region, research output in the SADC region and countries, which include authorship and co-publishing trends; citation analysis of research articles; the distribution of SADC water research articles in peer-reviewed journals and the organisations that are providing financial support for the research in the SADC region. These aspects provide a basis for the analysis of knowledge production of WARFSA-funded research projects.

Chapter 4

REVIEW OF LITERATURE ON KNOWLEDGE FOR POLICY

4.1 Introduction

In this chapter, the contributions of various researchers to the different uses of knowledge are presented, and specifically as their contributions relate to knowledge utilisation by policymakers. The chapter provides an introduction, and presents the contributions various researchers have made towards the instrumental, conceptual, symbolic and process use of knowledge. The chapter further discusses the 'two-communities theory' as presented by Nathan Caplan in 1979, where he argues that a gap exists between scientists and policymakers. The chapter further provides contributions towards bridging this apparent gap. Moreover, given the identification of the dissemination of primary research outputs in the HERG Payback Framework, this chapter presents contributions on the dissemination and utilisation of research, and further research impact assessment and challenges in linking research to research impacts.

4.2 Background

With the emergence of the age of professionalisation in the 1960s (see Stufflebeam, Madaus & Kellaghan, 2000), a greater awareness of the importance of accountability emerged throughout the world. With such a growing need for accountability and less funding for research (OECD, 1997), greater pressure was placed on universities to be more efficient and also more accountable (Massey, 1996). In the late 1980s and early 1990s, the importance of accountability grew even greater throughout the world, with phrases such as "performance management revolution" being coined in the late 1990s by scholars such as Neely (1999). This saw the introduction of an approach referred to as New Public Management (NPM) whereby private sector or market-based techniques are applied to public service (Gruening, 2001; Hood, 1991; 1994). Typical characteristics of NPM include budget cuts, privatisation, the separation of provision and production, contracting out, the customer concept competition, flexibility of management, the separation of politics and administration (Gruening, 2001). Moreover, NPM is characterised by accountability for performance, performance measurement, improved accounting and financial management, performance auditing, strategic planning, changed management styles, personnel management, the use of information technology (IT), improved regulation, streamlining of administrative structures, analysis and evaluation and enhanced citizen participation. Universities did not escape these characteristics of NPM, which resulted in profound outcomes (Bleiklie, Enders, Lepori & Musselin, 2010; Ferlie, Pettigrew, Ashburner & Fitzgerald, 1996; Milojevic, 1998; Schimank, 2005; Tolofari, 2005) and Shore (2010:20) even referring to the “schizophrenic university” due to the different functions which are expected of universities.

Along with the ‘age of professionalism’ in the 1960s, and the increased requirement for universities and research institutions to be accountable, researchers started developing various theoretical frameworks and definitions to describe knowledge utilisation better. This has led to a better understanding of the various factors and dimensions that drive successful (and sometimes unsuccessful) knowledge utilisation. Moreover, as indicated by scholars such as Amara, Ouimet and Landry (2004), knowledge utilisation has mainly centred on the instrumental, conceptual, and symbolic use of knowledge (see for example Amara et al., 2004; Estabrooks, 1999; Henry & Mark, 2003; Pelz, 1978). In addition, researchers such as Patton (2008) and Johnson (1998) identify the process use of knowledge. In the following section, instrumental, conceptual, symbolic and process use of knowledge will be discussed in more detail.

4.2.1 Instrumental use

The notion of the ‘instrumental use’ of research was first introduced in the literature in the 1970s by scholars such as Caplan (1974), Rich (1975), Weiss (1976) and Knorr (1976), recognising how policymakers make use of research in a specific, direct manner (Beyer, 1997). Weiss (1979), for example, discussed this issue in her *problem-solving model* (Weiss, 1979:427). Klautzer et al. (2011) refer to the policy-driven model (see Klautzer et al., 2011:201–209), where, as a linear model, problems are identified by policymakers. In order to solve the problem, social scientists derive empirical evidence from which to draw conclusions, which can be in the form of reviewing existing research or the purposeful commissioning of specific research to address the problem. The evidence can be qualitative or descriptive, quantitative or statistical relationships with the objective to clarify the situation and reduce the uncertainty and thus influence the decision the policymakers make.

Weiss’s *political model* (Weiss, 1979) also refers to instrumental use of knowledge, where predetermined positions are established and research is utilised to support such predetermined positions in order to increase the credibility and acceptance of decisions. The condition being that research is undertaken in an unbiased manner, and that the evidence of the research be available to all parties, to ensure equity is served through the research.

Moreover, decision-makers use certain criteria to describe and form an opinion on research studies (Weiss & Bucuvalas, 1980). These criteria are related to:

- the relevance the research has to the work of the decision-maker;
- the technical quality, objectivity and credibility (cogency) of the study ;

- decision-makers considering the plausibility of the research based on their prior knowledge and experience;
- the specific guidelines the research provides in terms of implementation and which are possible to implement; and
- the way the research calls into question the existing assumptions and state of affairs.

These findings are in line with findings by Caplan (1977:191).

In terms of the instrumental use of knowledge, social science research can be most useful to policymakers, when the policy issue is clearly defined and where the 'best' solution is identified, which requires research knowledge (Caplan, 1977:189). Caplan argues that policymakers are often so overwhelmed with complex responsibilities at a macro level, that they need assistance in identifying the problem issues and options available to address these issues. This is where the real purpose of research is made explicit, but it needs to be aligned to the policymaker's issues to be of real use to him or her. This can be achieved by the policymaker's understanding that the problem formulation is as essential as the solution, as defining the problem determines the solution Caplan, 1977). According to Caplan (1977), the policymaker and the researcher need to have a mutual understanding of the problems and policy issues. It is then for the researcher to understand further which parts of the policy issues need to be researched through the correct research methodology.

Caplan (1977) further argues that meta-level decision-making often involves two processes where policymakers initially gather and process the best available information to make an unbiased assessment of the policy issue, dealing with the internal logic of the problem. They then gather information to assess the political, social and also the value-based, ideological, administrative and economic ramifications of the policy issue, to address the external logic of the problem. In order to reach a policy decision, they weigh and reconcile the two viewpoints of information. Caplan (1977) defines this style as a *clinical orientation* to decision-making.

Rich (1977:200) describes instrumental use when referring to specific cases where users could cite and document the specific way in which information was used in decision-making or problem solving for example where programmes were changed based on direct decisions, which had been made based on evaluation results (Shadish, Cook & Leviton, 1991).

Landry, Amara and Lamari (2001b) refer to instrumental use of knowledge as cases where knowledge of a single study convinces users to make decisions which they would not have done otherwise.

4.2.2 Conceptual use

It is widely argued that in government agencies, the conceptual use of social science research is more widely employed than instrumental use (Amara et al., 2004). As a conceptual use of research, research creeps into the policymaking process (Weiss, 1977; 1979), indirectly and less specifically than directly as in the case of instrumental use (Beyer, 1997). Weiss (1979) argues in her *enlightenment model* (see Weiss, 1979:429) that value consensus is not a prerequisite for useful research and that research has a role as criticising society. Further, even if the implications of the research are not valuable for policymakers today, such influence might occur over time as new concepts and data emerge. Moreover, Weiss (1979) suggests that knowledge diffusion can take place through different channels, which could include professional journals, mass media and conversations, and in such a way become part of the general discussions and influence decisions. Weiss (1979) further argues that research can be part of the intellectual enterprise of society where, at any given time, specific topics are discussed and debated. Here, policy and social science both respond consciously or unconsciously to fashions of social thought and influence each other, appropriating resources for social science research and political discussion and influence.

Caplan (1979) suggests that meta-level decision-makers rely greatly on such external sources of information to access social science information in addition to agency-sourced information, although these external sources are rarely cited as empirically grounded information. Caplan (1979) further argues that in order for knowledge to be useful, it needs not necessarily conform to policymakers' values and goals, and knowledge derived from research inadvertently influences general thinking rather than targeting very specific issues of policymakers. Caplan (1979) argues that meta-level decision-makers rely not only on a single piece of information, but a final policy decision is made up from a variety of sources. These sources include scientific (hard) knowledge, which is research-based, quantitative and written in scientific language and also "extra-scientific" (soft) knowledge (Caplan, 1979:464), which is non-research-based, qualitative and written in a lay language. Sources of knowledge can further be at a conceptual level (or conceptual utilisation), which results in a judgement or perspective, which is applied broadly. Caplan (1977:188) suggests that 'hard' knowledge is often only of instrumental importance, and decisions are often based on 'soft' knowledge when it comes to the considerations of the social consequences of a policy decision.

In his article, Rich (1977) reports on the experiences of 38 respondents of the Continuous National Survey (CNS) over eighteen months. Rich makes a distinction between instrumental and conceptual use, where he concludes that in the specific case study, conceptual use of information has a longer-term influence on use (from three to six months and even longer) than instrumental use of information, which is used within the first three months. Rich refers to a "first wave" of information use (within three months) and a "second wave" thereafter (Rich, 1977:199-200). He further argues that such conceptual use of information influences a decision-maker's thinking without making a specific link to a single document. He then further refers to planned information "in the future" (Rich, 1977:200).

Rich (1979) further encourages the development of new measurement models which, at the time, were dominated by case studies (of programmes and innovations) and user surveys. Rich argues that within such case studies and user surveys, a bias exists for documenting instrumental use of knowledge, with less attention paid to the conceptual use of knowledge where a more indirect link exist between an action and the information that guided the action. In conclusion, Rich states that the main purpose of scientists is not just to advance the status of their particular discipline, but to apply knowledge to the needs of society, and not adopting society to meet the needs of science, where knowledge transfer and utilisation play a major role in central activities of "planned social change" (Rich, 1979:28).

4.2.3 Symbolic use

Symbolic use of research can be employed to support predetermined political positions by policymakers (Albæk, 1995; Beyer, 1997; Feldman & March, 1981; Lavis et al., 2002; Pelz & Horsley, 1981), and as argued by Weiss (1979) in her *tactical model* (see Weiss, 1979:429), policymakers may be pressured to act on a specific issue, or mandated goals (Rich & Oh, 1994). By commissioning specific research, policymakers can alleviate such pressure to act and use research as an indication that they are responding to the issue and the research becomes a proof of responsiveness (Weiss, 1979:429). The response, however, is that the act of research is used to maintain a political position, or as a delaying tactic, or to deflect criticism, rather than aimed at addressing a problem through the research as part of bureaucratic politics (Weiss, 1979:429). Organisations can further use expert knowledge to enhance its legitimacy over a particular policy area and to substantiate preferences towards certain political views (Boswell, 2008; Herbst, 2003)

From a users' point of view, Landry, Amara and Lamari (2001a) suggest that many factors related to knowledge utilisation are not under the researcher's control, and the best course of action would be to make the users more willing to consider new ideas or suggestions in relation to social science research. This can be achieved through symbolic interventions, which indicate that social science research is used more extensively than assumed, which could lead to users paying more attention to the research results.

In a survey of 833 government officials, Amara et al. (2004) focussed specifically on the instrumental, conceptual and symbolic use of university research by government agencies, and concluded that all three types of use play a significant role in government agencies. However, conceptual use is found more frequently than symbolic use of research, in the day-to-day activities of managers, while symbolic use in turn is more important than instrumental use. Moreover, Amara et al.'s (2004) study found that large differences exist between policy domains concerning the different uses, where policy domains such as education, health and social services rely on conceptual and symbolic use of university research, where such research is complementary to their daily work. Amara et al. (2004) argues that this is due to managers and professionals in government agencies operating in diversified and complex contexts, which require complementary research perspectives.

4.2.4 Process use

Finally, *process use* occurs through the involvement and participation of stakeholders in research, which results in experiential learning and reflection (Patton, 2008; 1998; Preskill & Torres, 2000). Through process use, long-term payoff may occur, such as improvements in skill, communication and decision-making (Johnson, 1998). In Weiss's *interactive model* (Weiss, 1979), inputs such as experience, judgement and political insight provide inputs into the policy-making process through a non-linear process. Weiss argues that these inputs are provided by various role players, such as administrators, practitioners, politicians, planners, clients, interest groups, aids, friends, social scientists and journalists. These role players provide a pool of talent, beliefs and understanding, which could progressively be accessed in order to address the problem, and they form part of a complicated process, which includes experience, political insight, pressure, social technologies and judgement.

A framework, which could be associated with the process use of knowledge, is the advocacy coalition framework (ACF). Being influenced by the work of Heclo (1974), the ACF was initially presented by Sabatier in his article, "An advocacy coalition framework of policy change and the role of policy-orientated learning therein" (Sabatier, 1988). The ACF presents a more general model of policymaking over a longer period, with timespans of decades or more. In the article, Sabatier states that the ACF focusses on the belief systems of advocacy coalitions and the role these play in understanding the role of policy analysis in policy-orientated learning, and how such learning could effect changes in government programmes. The ACF is based on the interaction between political elites within the political community, and how they respond to changing socio-economic and political conditions and how the elites, over time, gradually alter their belief systems as a result of formal policy analysis and also trial and error learning.

Sabatier and Jenkins-Smith jointly developed the advocacy coalition framework as presented in the 1993 book, *Policy change and learning: An advocacy coalition approach* (Sabatier & Jenkins-Smith, 1993), where the ACF is presented as a system-based model with many stages of the policy cycle, including aspects of both top-down and bottom-up approaches to implementation. The book is based on six case studies (four discussed by other researchers), and concluded with a critical assessment and revision of the framework.

A few years later, Jenkins-Smith and Sabatier published an updated ACF (Jenkins-Smith & Sabatier, 1994), based on four premises, namely:

1) the understanding of the process of policy change, and the learning within this process over a period of 10 years and more (which was influenced by the enlightenment model of Weiss [1979] as discussed earlier in this document);
2) policy change over this time through a focus on policy subsystems (or domains), which comprised actors from various levels of government and also journalists, researchers and policy analysts who generate, disseminate and evaluate policies;
3) the inclusion of an intergovernmental dimension, at all levels of government within the subsystems; and
4) public policies or programmes can be conceptualised in the same manner as belief systems with sets of value priorities and causal relationships.

These belief systems of coalitions are organised into a hierarchical, tri-partite structure, with broader beliefs limited to specific beliefs (Jenkins-Smith & Sabatier 1994:180). Belief systems comprise 'deep-core' beliefs at the highest level, which are highly resistant to change, followed by 'policy core' beliefs, which represent the basic normative commitments of the coalition, such as fundamental value priorities, which cut across the entire policy subsystem or domain. Such policy core beliefs are less rigid as presented by Weiss's enlightenment model (Weiss, 1979). Finally, secondary aspects of the belief system of a coalition within the policy domain comprise a large set of narrower beliefs, which are concerned with the seriousness of a problem, relative importance of various causal factors, policy preferences, the design of institutions and evaluations of actors' performances.

Figure 4.1 presents an overview of the ACF as originally presented by Jenkins-Smith and Sabatier in 1994, which indicates that coalitions adopt different strategies to influence government institutions to be more in line with the objectives of the coalitions. Policy brokers mediate conflicting strategies between the coalitions, who are primarily concerned with finding a reasonable compromise, which leads to more government programmes and then to policy outputs. Based on the decisions taken and their resulting outcomes, coalitions may revise their beliefs, on primarily their secondary aspects, and then change their strategies. The 1994 version of the ACF further argues that policy-orientated learning is attained through feedback loops, and result from experience and a better understating of the external dynamics of problem parameters and the factors affecting them. In addition, changes in relevant socio-economic conditions and changes in personnel could influence the composition and resources of coalitions, which would influence the public policy in the subsystem.

The basic argument of the ACF is that changes in the core aspects of policy are usually the result of an anxiety in non-cognitive factors external to the subsystem, which could include the changes in macro-economic conditions or the rise of a new systematic governing coalition (Jenkins-Smith & Sabatier 1994:183).

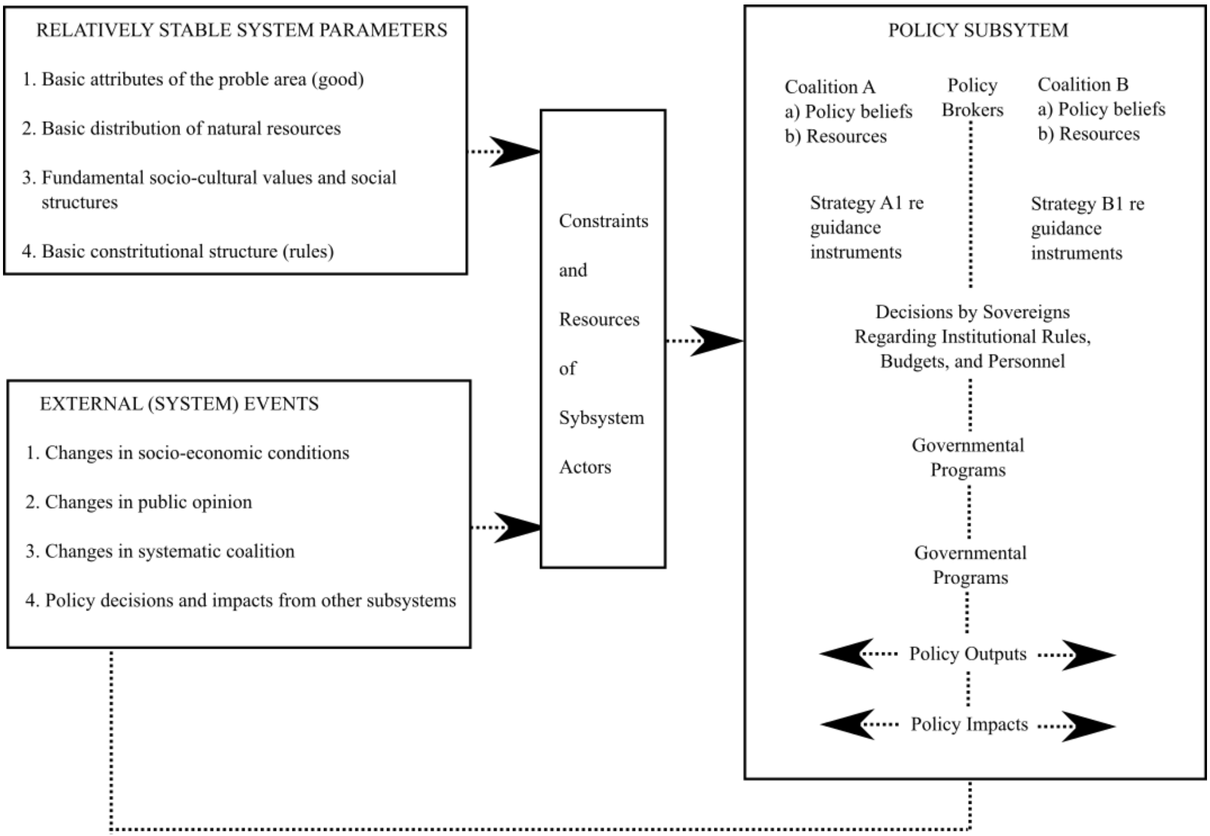


Figure 4.1: Revised diagram of the advocacy coalition framework (1994)

Source: Jenkins-Smith and Sabatier (1994)

In addition, the ACF places scientific and technical information central to many of its hypotheses, with a range of nine hypotheses identified (Jenkins-Smith & Sabatier 1994:183). The first three hypotheses are concerned with advocacy coalition and are based on the premise that the coalition is being held together by an agreement over the policy *core* beliefs. The following two hypotheses are concerned with policy change and hypothesise that policy core attributes will not change as long as the dominant coalition, which introduced the policy, stays in power, even though the secondary aspects might change. The only way the core attributes could change, is through a shock from *outside* the subsystem, which fundamentally reallocates the political resources within the subsystem (Jenkins-Smith & Sabatier 1994). The final four hypotheses are concerned with coalition learning and the conditions, which are conducive to policy-orientated learning between coalitions (Jenkins-Smith & Sabatier 1994:184). The hypotheses are based on the premise that coalitions resist changes in policy core beliefs and will only do so if solid empirical evidence is presented in situations where intermediate levels of conflict exists "high enough to be worth expending analytical resources but not involving direct normative conflict" (Jenkins-Smith & Sabatier, 1994:184) .

Originally, the ACF focussed on two paths to policy change, with the first path defined as shifts in the policy core attributes of the subsystem (such as general changes in socio-economic conditions and changes in coalitions in government), and influenced by external shocks or events. The second path to policy change is through policy-orientated learning, gained through experience and/or new information. According to Weible, Sabatier, Jenkins-Smith, Nohrstedt, Henry and DeLeon (2011), these paths were identified through

- a response to a longer-term view on policy change (10 years and more);
- a more complex inspection of the subsystems to include researchers and also inter-government relations;
- added focus on the role of science and policy analysis in public policy; and
- a need for a more realistic model of the individual, which is rooted in the psychology rather than microeconomics.

Since the early 1990s, the ACF has been revised and updated with a later version identifying a third and fourth path to policy change as presented by Sabatier and Weible (2007). One of the major contributions of this 2007 revision is presented in Figure 4.2, and highlights the distinction between the policy subsystem and the broader political environment defined by relative stable parameters and external system events. These are constrained by long-term coalition opportunities, external systems events and short-term constraints and resources of sub-system actors.

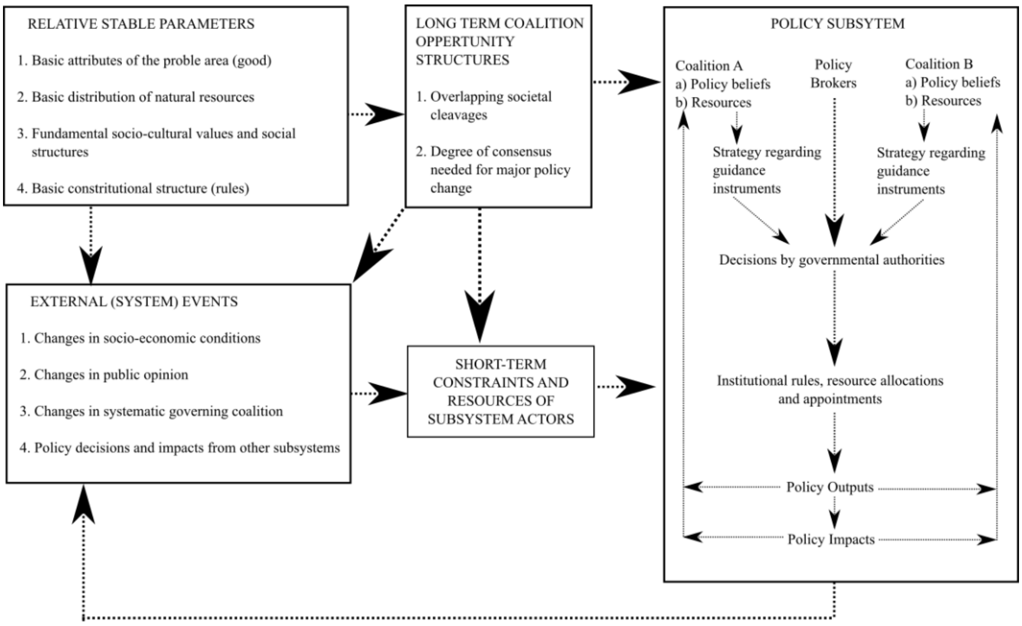


Figure 4.2: The updated advocacy coalition framework flow diagram (2007)

Source: Sabatier and Weible (2007)

The third path to policy change is internal subsystem events (as appose to external events), which occur within the subsystem and emphasise failures in the current subsystem. A fourth path presents "professional forums" (Weible et al., 2009) where an institutional setting is provided which allows coalitions to negotiate, agree and implement agreements within a safe environment. Nine conditions are provided (Sabatier & Weible 2007:206-207), which could affect the likelihood of policy change, which includes a hurting stalemate, effective leadership, consensus-based decision rules, diverse funding, duration of process and commitment of members, a focus on empirical issues, an emphasis on building trust, and a lack of alternative venues (Weible et al., 2009).

4.1.5 Summary

To conclude, the advocacy coalition framework (ACF) as presented by Jenkins-Smith and Sabatier in the early 1990s, argues that changes in the core aspects of a policy are usually due to the uncertainty in factors external to the subsystem, such as changes in macro-economic conditions and new governing coalitions. The original ACF focussed on two paths for policy change, with the one path identifying shifts in the policy core attributes (such as changes in government coalitions and socio-economic conditions), and the second path to policy change through policy-orientated learning, which is gained through learning and/or new information. Later versions of the ACF (Sabatier & Weible, 2007) identified two more paths to policy change with the third being internal subsystem events, and the fourth being professional forums presented to negotiate, agree and implement agreements in a safe environment.

With a better understanding of the different uses of knowledge, and the contribution various authors have made to the field, various researchers have argued that a cultural gap exists between researchers and decision-makers in government agencies, which leads to a lack of understanding and low levels of research uptake (Caplan, 1979; Frenk, 1992; Landry, Lamari & Amara, 2003; Rich, 1979; Rich & Oh, 1994; Webber, 1987). In his 1979 article, Nathan Caplan (1979) presents the two-communities theory and argues that the social scientist is concerned with 'pure' science, while by contrast, policymakers are 'action-orientated', practical persons concerned with obvious and immediate issues. According to Caplan, this creates a gap between the knowledge producers and policymakers.

In the next section, the two-communities theory is discussed in detail.

4.3 The two-communities theory

In his 1979 article, Caplan distinguishes between meta-level problems (policy matters, which affect the nation as a whole) and micro-level decision-making (day-to-day policy issues of limited significance). Reflecting on a study, which he conducted in 1975, where 204 upper-level executives in the United States (US) government were interviewed, it was found that 90% of these executives reported use of scientific information at micro level and associated with policy issues of limited significance (Caplan, Morrison & Stambaugh, 1975). The study further found that a large number of these uses addressed administrative policy issues through the instrumental or direct use of scientific knowledge. Moreover, the participating executives further reported that approximately 10% of instances involved policy matters at macro level, which affected the nation as a whole.

In a later study, Rich (1991) identified five factors, which contributed towards the apparent gap between the culture of science and the culture of government:

1) apparent distrust and even antagonism between the cultures of the two communities;
2) the two communities appeared to have alternative or even competing reward systems, where researchers and scholars are rewarded for research productivity "scholarships for the sake of scholarships" (Rich, 1991:324), and not necessarily, as in the case of programme managers, for providing concrete results.
3) Rich (1991) argues that there is a preference in the use of alternative language or jargon, where scholars communicate with their peers in language designed for academic journals. In order to increase knowledge utilisation, concise reports need to be produced, which are clearly written in a language that is understood by all members of a particular group;
4) according to Rich (1991), researchers and government officials work in terms of different time frames, as government officials are often bound by deadlines and require information adhering to such deadlines often arguing to have some information now, than all the information later. On the other hand, researchers are rewarded by high-quality research, even if it is after such deadlines;
5) Rich (1991) also argues that researchers need to be more aware of the needs of government officials, and align the relevance of research to such needs, especially to the extent to which the relevance of the research could direct which actions should be taken or justify decisions, which have been reached.

4.3.1 Bridging the two-communities gap – specialists, agencies and knowledge brokers

In order to bridge the gap between the two communities, Caplan (1977:194) highlights the role of information specialists with different combinations of roles and skills that can link policymakers and knowledge producers by taking into account the practical factors affecting both the producer and the user of knowledge. Such knowledge would vary depending on the information and policy issues involved. In addition, personal relationships that involve characteristics, such as trust, confidence and empathy, would further assist in bridging the apparent gap. In addition, he suggests a set of arrangements *deliberately* designed to supplement agency-provided information with other kinds of information, especially in addressing macro-level policy information (Caplan, 1979).

It is also pertinent to refer to earlier work of Havelock (1969), where he argues that from a problem-solver perspective, there are both receivers and external change agents which work together change agents are individuals or groups who have the resources to assist receivers to bring about change (see Havelock, 1969:44). Imperative though, even if the change process is initiated by the receiver or change agent, the receiver must have the desire to change and must participate fully in bringing the change about (Havelock, 1969:44).

In response to the work of Caplan (1977, 1979), various additional arguments have been put forward to bridge the apparent gap between the two communities.

Researchers could provide outputs of their research in formats and language (non-scientific) with which they are familiar (Caplan, 1979; Dunn, 1980; Nguyen, 2014; Rich & Oh, 1994; Webber, 1987; Weiss, 1973) and use available resources to make reports more appealing with specific recommendations, interventions and conclusions for the decision-makers (Huberman, 1994; Landry et al., 2003).

Lindquist (1990) also discusses the existence of a third community inside and outside of government which does not necessarily comprise policymakers or organisations who are fully committed to providing social science, but who are committed to providing policy-relevant data, research and analysis, and who thus influence high-level decision-making. In addition, these third communities could be established through people changing careers from inside government to outside government, and vice versa (Lindquist, 2001). The various third community groups are presented in Figure 4.3, and could comprise government–policy shops, task forces and university research centres where the ideas are exchanged and disseminated. In addition, third community groups could comprise commissions, councils, legislative committees, large consulting firms and boutique/specialised consultants, interest groups, associations and think-tanks. These third-community groups operate in the private or public sector, with private and public access to policy inquiries (Lindquist, 2001).

		Access to policy inquiry	
		Private	Public
Sectors of organisation	Private sector	Policy shops Task forces Centres	Commissions Councils Legislative committees
	Public sector	Consultants -big firms -boutique	Interest groups Associations Think-tanks

Figure 4.3: The third community of policy influence

Source: Lindquist (2001)

This notion of outside organisations lobbying legislature policymakers to influence policy decisions, is also put forward by Havelock (1969), Rich (1990) and the ACF (Jenkins-Smith & Sabatier, 1994; Sabatier & Weible, 2007; Weible et al., 2009). Knowledge brokers also play an important role in bridging the gap between knowledge producers and decision-makers (Fisher, 2008; Lavis, Robertson, Woodside, McLeod & Abelson, 2003; Moore, Redman, Haines & Todd, 2011; Van Kammen, De Savigny & Sewankambo, 2006). Developing a knowledge broker programme (Dagenais, Somé, Boileau-Falardeau, McSween-Cadieux & Ridde, 2015) further indicates how a structured approach to knowledge brokering (KB) could provide results in promoting knowledge utilisation.

In addition, a study conducted by Amara et al. (2004) also highlighted factors which could lead to an increase in knowledge utilisation, specifically in relation to university research, such as an increase in qualitative studies, needs-focussed research that take the context of the government agency into consideration, and research that is relevant to the policy domains of policymakers. Researchers could further increase their interaction with managers and professionals in government agencies, and visa-versa.

4.3.2 Dissemination and utilisation

Having identified an apparent cultural gap between researchers and decision-makers, with reasons and possible remedies to bridge this cultural gap, the role of disseminating information in the eventual research uptake becomes apparent. Researchers have distinguished between the *dissemination* of knowledge being the planned and deliberate efforts to persuade target groups to utilise knowledge, whereas *diffusion* is the ‘passive spread’ of knowledge (Greenhalgh, Toon & Russell, 2003; Greenhalgh, Robert, Macfarlane, Bate & Kyriakidou, 2004). As early as 1969, Havelock presented seven factors that were deemed important for successful dissemination and utilisation (D&U), namely

- the *linkage* between the number, variety and mutual contacts between the user system (decision-makers) and the resource system (researchers);
- the degree of *structure* and co-ordination in the resource system, user system and the dissemination/utilisation strategy;
- an *openness* is required so that change can be desirable and possible coupled with a willingness and readiness to accept outside help and to listen to the need of others and a social climate, which is favourable to change;
- *capacity* is required to marshal diverse resources;
- *rewards,* in the form of positive reinforcements, which are planned and structured to address frequency, immediacy, amount and mutuality;
- *proximity* to resources and other users is required; and
- *synergy* in the variety, persistence, frequency and the number of messages and media is required to produce a knowledge utilisation effect.

Amara et al. (2004) echo these sentiments when they argue that decision-makers have to make an effort in engaging resources to acquire knowledge as produced by researchers, where decision-makers could organise meetings to discuss subjects and scope results from researchers.

In his article, *The pursuit of knowledge*, Rich (1979:20) argues that utilisation should not be taken for granted as it is “a complex process involving bureaucratic, ethical, attitudinal, and social considerations that took precedence over the information conveyed”. Rich also argues that merely because information was provided in a timely, relevant, objective and user-friendly manner and further disseminated to the right people, does not guarantee the use of such knowledge, and the process itself needs to be understood in the context of overall social problem solving.

Knott and Wildavsky (1980) claim that a school of thought exist that argue that utilisation refers to the immediate and direct outcomes of a major research project on a policy, and that others again believed that ‘research utilisation’ refers to the long-term process in which accumulated results of research over time enlighten policy (for example the enlightenment model) (Weiss, 1979). Knott and Wildavsky (1980) propose stages of utilisation where each stage is a link in the process of utilisation. These stages should be kept distinct, and viewed as stages with strategies of dissemination related to a particular level of utilisation. Seven stages were identified, as discussed below:

→ Stage 1: Reception

Utilisation takes place when the communication reached the policymaker’s ‘in-basket’, and the policymakers or advisors receive the data, rather staying with the analyst.

→ Stage 2: Cognition

At this stage, the policymaker must read, digest and understand the information in order for utilisation to occur.

→ Stage 3: Reference

Should the policymaker change his or her preference, understanding of probabilities and magnitudes of outcomes and utilisation would occur. This change could be important, as it would influence the policymaker policy priorities in the long run.

→ Stage 4: Effort

Should the policymaker end up making an effort in challenging policy change successfully or unsuccessfully, information has influenced his or her actions, and utilisation has occurred.

→ Stage 5: Adoption

Knott and Wildavsky (1980) argue that policy results is a proper standard for knowledge utilisation, as such policy results influence policy outcomes, and not just as an input to the policy process

→ Stage 6: Implementation

Adopted policy should become practice as a standard of utilisation.

→ Stage 7: Impact

As a final stage, Knott and Wildavsky (1980) argue that only when tangible benefits to society have been achieved, through policy which has been influenced by information, could one claim that utilisation had taken place.

In addition, Knott and Wildavsky (1980:541) argue that there are at least three obstacles, which limit the use of knowledge by decision-makers;

- the knowledge does not exist;
- where information does exist, decision-makers are ignorant about the knowledge; and
- the decision-makers know about the knowledge, but refuse to use it.

Finally, Knott and Wildavsky (1980:573) conclude that dissemination could be a solution to underutilisation **if** the knowledge is disseminated to specific people under specific circumstances. They further argue that premature dissemination, in the absence of knowledge, could contribute to an overload of information, thus making dissemination a potential cause to the underutilisation of knowledge. Further, the *natural processes of dissemination* should be supported, as they could be more effective and cheaper than *artificial processes of dissemination.* Natural processes of dissemination could include the natural exchange of information among, for example, teachers who share best practices through associations, whereas artificial processes of dissemination require deliberate and organised processes. Only when natural dissemination fails, should *artificial dissemination* be introduced, and then only selective application strategies to supplement natural processes (Knott & Wildavsky, 1980). *Passive exchanges of information* are also supported where the costs of obtaining information are left to the policymakers, as opposed to *active exchanges,* which place the responsibility on disseminators, with an emphasis on the exchanges of information through clearing houses, data banks, journals. Should *people be moved*, Knott and Wildavsky (1980:573–574) argue that the initiative should lie with the policymakers to take the responsibility to exchange information with the information producer. Where dissemination is required, it should be combined with better analysis of policymaker needs; thus, leading to better screening of information for better interpretation of difficulties that might be encountered by decision-makers (Knott & Wildavsky, 1980).

Drawing on the work of Knott and Wildavsky (1980) the authors Landry, Amara and Lamari (2001a; 2001b) developed the *index of utilisation*. In their research, Landry et al. (2001a:399401) focussed on the *factors why researchers succeed* in climbing the "ladder of knowledge utilisation". These factors, or barriers of entry, could include transaction costs as researchers climb the ladder of utilisation, and not only the factors, which explain why research is utilised. The results from the study (Landry et al., 2001a) showed that researchers, after deciding to incur costs to ensure knowledge utilisation, should also decide at what 'echelon' of the ladder of knowledge utilisation they should enter. This entry into the ladder of knowledge utilisation determines the extent to which the researcher would incur costs related to knowledge utilisation, and the degree to which he or she succeeds in insuring knowledge utilisation. Moreover, they should decide on the number of echelons they wish to climb this is argued to be one of the most critical decisions in knowledge utilisation (Landry et al., 2001a:412).

The research (Landry et al., 2001a) further argues that the *type of research method* (quantitative or qualitative) used by researchers to produce research results, is of much less importance and not a very good predictor, nor a lever of intervention, determining knowledge utilisation. On the other hand, *dissemination efforts* undertaken by researchers, provide a better predictor of utilisation in social sciences (except in anthropology and social work), and it is argued that increased dissemination (through "sustained and intense interaction") (Landry et al., 2003:195) could increase knowledge utilisation, which, with the adaptation of products, is within the control of researchers. Increasing incentives (such as compensation and rewards of transaction costs) which are targeted at dissemination, could therefore lead to an increase in knowledge utilisation of social science research (Landry et al., 2001a). Nguyen (2014) emphasises 'the power of plain language', which enables the readers to find what they need, understand what they find, and act appropriately on that understanding. This "plain language" (Nguyen, 2014:582) could also differ between the general audience and policymakers. Further, researchers should work with their colleagues in multidisciplinary design of research dissemination, and make use of infographics as part of visual communication (Nguyen, 2014:582–583). Close relationships should also be established with the media, as miscommunication and a lack of science understanding have led to misinformed coverage and misinterpreted research results (Nguyen, 2014:583–584).

From a *researchers' context*, Landry et al. (2001a) argue that researchers with a greater number of research outputs, such as publications, would be more likely to have a higher use of knowledge, as they would produce more by-products from their research to be used by practitioners, professionals and decision-makers. This higher number of publications could lead to scientific credibility.

4.4 Further developments relating to knowledge production

Since the early 1990s and 2000s, new ideas came to the fore related to interdisciplinary research (for example Klein, 1990 and Moran, 2002), and where researchers from different disciplines work jointly in an integrative process to develop a shared conceptual framework that synthesises and extends beyond discipline-specific theories and methods to create new models to address common research problems. In addition, new ideas developed promoting the broader co-production and uptake of knowledge, which involved a wide range of role players from the research community, policymakers, industry and society – particularly with the publication of the book *The new production of knowledge – The dynamics of science and research in contemporary societies* (Gibbons, Limoges, Nowotny, Schwartzman, Scott, and Trow, 1994). Here, Michael Gibbons and his co-authors introduce the 'new production of knowledge', or Mode 2 knowledge production. The authors would later describe the difference between Mode 1 and Mode 2 knowledge production as Mode 1 being the traditional paradigm of scientific discovery where knowledge production was characterised by the "hegemony of disciplinary science, with its strong sense of an internal hierarchy between the disciplines and driven by the autonomy of scientists and their host institutions, the universities". In Mode 2 knowledge production is more "socially distributed, application-orientated, trans-disciplinary and subject to multiple accountabilities" (Nowotny, Scott & Gibbons, 2003:179), and where "society is moving into a position where it is increasingly able to communicate its wishes, desire and fears to science" (Gibbons & Nowotny, 2001:71).

In Gibbons et al. (1994:4–8), the authors present five characteristics of Mode 2 knowledge, which are briefly presented:

- The first characteristic is the *context of application* (different from the process of application, which is more linear), and given that knowledge is produced in a particular culture and set of social arrangements, it describes the total environment in which scientific methodologies are developed and outcomes are disseminated, and where uses are defined to address scientific problems. In Mode 2, knowledge production is "the outcome of a process in which supply and demand factors can be said to operate, but the sources of supply are increasingly diverse, as are the demands for differentiated forms of specialist knowledge" (Gibbons et al., 1994:4). This leads to knowledge being distributed throughout society.

  It is worth to take a short detour and reflect on the follow-up book, *Re-thinking science* (Nowotny, Scott and Gibbons, 2001), where the authors provide further explications relating to the context of knowledge. First, varying degrees of contextualisation were presented as 'weak', 'middle-range' (where the majority of Mode 2 knowledge production can be found) and 'strong' contextualisation. To give a sense of how the contextualisation is defined, 'middle-range contextualisation' is characterised by 'trading zones' and 'transaction spaces' where, for example the risks of certain technological developments are debated and negotiated and where the outcome is potentially achieved as 'Mode-2 objects' (Nowotny et al., 2001:145–147). 'Strong contextualisation' is characterised by researchers who have the opportunity, and who are willing to respond to signals received from society and where 'dynamic, two-way' communication takes place and seeks to control science through bureaucratic means (Nowotny et al., 2001:131).

  Secondly, given that reliability is the prerequisite for science, the authors further argue that the more highly contextualised knowledge become, the more reliable also it becomes, and they introduce the concept 'socially robust knowledge' (Nowotny et al., 2001:168). The authors further argue that reliability and 'good science' are not just the domain of scientists, but also the concern of lawyers, accountants and many professions who are equally concerned that the outcome of work should be correct, with the difference being that scientists test results 'against Nature' and not against rules and procedures designed to adhere to accounting standards. This larger potential community endlessly challenge the notion of reliable knowledge, especially where reliable knowledge is bound and 'policed' by a small number of peers through disciplinary cohesion, in order to limit 'contamination' by the social context (Nowotny et al., 2001:177). Finally, the authors introduce the concept of the agora or structured 'social space' where the transformation of knowledge production takes place, providing an additional explication of contextualisation (Nowotny et al., 2001:201).

- The second characteristic of Mode 2 is that knowledge production is *transdisciplinary*, and not derived from pre-existing disciplines, or contributing to the formation of new disciplines, as in the case of inter- or multi-disciplinary research, and it encapsulates the expertise of individual researchers in research teams. In Mode 2, the enquiry "is guided by specific consensus as to appropriate cognitive and social practice", and where the consensus evolves with the context of application (Gibbons et al., 1994:4). The authors further highlight four characteristics of transdisciplinarity, where the first characteristic is the development of a district and evolving framework. The development of the theoretical framework involves 'genuine creativity' and, even though elements of existing knowledge would be found in the framework, once theoretical consensus is attained, the framework cannot be reduced to the disciplinary parts. The second characteristic of transdisciplinarity is that the solution is cumulative and develops its own distinct theoretical structures, research methods and modes of practice, and is not necessarily a contribution to prevailing disciplinary fields. Thirdly, the results of transdisciplinary knowledge production are communicated to those who have participated in the knowledge production, unlike in Mode 1, where results are communicated through institutional channels. The outcome of such communication is that initial diffusion of results is achieved as part of the process of the knowledge production, and available to the communication networks for further configurations. Lastly, transdisciplinarity is dynamic, and it is difficult to predict how knowledge will be applied. Moreover, new knowledge does not necessarily fit into any of the disciplines that contributed to the solution and its application. Here, communication, which continuously evolves, is very important, with communication links established and maintained through formal and informal channels.
- The third characteristic is the *greater diversity of sites* where knowledge can be created, which is not limited to universities, but include research centres, government agencies, industrial laboratories and think-tanks consultancies, which are linked through functional networks of communication and are increasingly moving away from traditional disciplinary activities into societal context.
- As a fourth characteristic, Mode 2 knowledge production is characterised as being highly *reflexive* to the public interest and end-users, where the potential impact of research is built into the research process from the start, and forms part of the context of application. This increased sensitivity to the impact of the research further translates into an increased notion of accountability, as the problem solving environments influence the topic choice, research design and end-users (Nowotny et al., 2003:187).

- The last and fifth characteristic of Mode 2 knowledge production are the novel forms of *quality control* where the quality of work is no longer limited to peers in a specific discipline and based on previous contributions by individuals. In Mode 2, additional and 'diverse intellectual interests' are drawn from various spheres, which include social, economic and political interests. In 2003, Nowotny et al. argued that there are multiple definitions of quality, which complicates quality control, and further, as a veiled warning, complicate and could compromise, the knowledge upon which policymakers and funding agencies rely.

In addition to the five characteristics, Gibbons et al. (1994) present a number of contexts in which Mode 2 knowledge production was developed, with the first being the *commercialisation of research*. This commercialisation of research can be regarded either as a threat to the autonomy of scientific research, which could lead to the decline in the quality of the research, or the commercialisation of research is revitalised in terms of its priorities, uses and resources from private institutions.

The second context was the development of *mass higher education*, where the numbers of students have increased substantially, along with the expansion of research. Nowotny et al. (2003:188) refer to 'tensions" between mass access and high-quality research, which are reduced in Mode 2 where higher education is 'democratised' and knowledge production is distributed in the wider society.

The third context is the *role of humanities* in the production of knowledge, due to it being more engaging by nature and embodying the notions of reflexivity Gibbons et al. (1994). Moreover, it is argued that the humanities emphasise the essential contextualisation of Mode 2 knowledge production.

As a fourth context, Mode 2 is a useful tool to unlock increasing demand through *globalisation*, where for example, industrial nations can only maintain a competitive advantage through skills and resources that are not easily imitated (Gibbons et al., 1994:111). In addition, firms need to stay updated on the latest knowledge and have instant access to it, through highly specialised knowledge, which can identify problems and provide solutions.

By their own admission, the authors admit that the ideas relating to the final two contexts were least developed in 1994 (Nowotny et al., 2003:189). The fifth context relates to the potential to *reconfigure institutions*, given the proliferation of various knowledge–producing, knowledge–mediating and knowledge–diffusing institutions, such as professional societies, government and corporate R&D laboratories and think-tanks (to name but a few). Gibbons et al. (1994) examined how the flexibility of Mode 2 knowledge production affects institutional structures and procedures and how it relates to quality control.

As a sixth and final context, the authors argue that Mode 2 knowledge needs to be *managed* in new ways, given the distributed and open-ended nature of knowledge production in Mode 2 (Gibbons et al., 1994:161). The authors further argue that knowledge production should be decentralised through the establishment of 'lean centres', where few administrators are employed and networks of innovation are stimulated by many stakeholders. In addition, the authors argue that governments, in conjunction with other agencies need to function as 'honest brokers', given that in distributed knowledge production, more actors, who are not necessarily technical experts, will be involved (Gibbons et al., 1994:162).

During this time, concepts such as the triple helix model (Etzkowitz & Leydesdorff, 1998), where the knowledge base of the economy is analysed in terms of university–industry–government relations, were also introduced. This came about especially at a time when universities adopted a 'third mission', apart from teaching and research, and was evident through the creation of science parks, the establishment of spin-off companies and technology-transfer offices. Here, the authors argue that a spiral model of innovation creates different stages of the capitalisation of knowledge. These are achieved through four dimensions:

- the first being the internal transformation of each of the helixes;
- second, the influence of each helix on the other;
- the third being the new institutional structures resulting from the interaction between the helixes; and
- the last dimension being the recursive effect of the spirals on the three helices, and further on the larger society.

The triple helix model, with its spiralling helixes, challenge the linear model of innovation, from basic research to applied research and to product development, and leads new frontiers of "endless transitions" of innovation, with the complex social relations increasingly locked into technological innovation and organisational reform (Etzkowitz & Leydesdorff, 1998:205–208).

In essence, these concepts argue that scientific knowledge is part of a larger innovation process, and that researchers, policymakers, industry role players and various societal stakeholders participate in networks of research and innovation *ecosystems* to co-create new knowledge. These ideas were a progression from the two-communities theory as presented previously (see section 4.3), and where multiple communities now participate in knowledge production. Where such multiple communities collaborate, parties involved bring specific expertise to the table, translating it into the cross-fertilisation of ideas and finding solutions to complex societal challenges, especially where such groups are well connected (LERU, 2016a; 2016b).

In addition, such multi-stakeholder networks focus on ways to invest in the long term; thus, finding sustainable methods to bridge gaps between the researchers, policymakers and various other stakeholders. Scientists however caution that where various stakeholders participate in 'team-science' initiatives, topics related to system factors need to be considered and researched and not neglected, especially relating to the institutional support for interdisciplinary and transdisciplinary collaborations the large-scale public and private funding of initiatives, and societal concerns relating to accountability of scientific research (Stokols, Hall, Taylor & Moser, 2008).

Having described the different uses of knowledge and contributions towards bridging the apparent gap between scientists and policymakers, the question can be asked on the outcome of research, and the assessment of the outcome of the research. With increasing emphasis on research projects and programmes to provide evidence of outcomes, research on evaluation (RoE) has increased in the past decade and contributed to an ever-expanding literature base (Coryn et al., 2017; UK Collaborative on Development Research [UKCDR], 2013). The next section reports on contributions in measuring knowledge utilisation and challenges in linking research to impacts.

4.5 Research impact assessment

In terms of measuring knowledge utilisation, Rich (1991:328) argues that measuring knowledge utilisation is a *process*, and not a single event. According to Rich, the process consists of various generic steps, such as information *transmission*; information *pickup*; information *processing* and information *application*, as presented in Figure 4.4. These steps can take a few minutes or occur over a long period, and could involve a single user who could perform these steps cognitively, within an organisation within a network, or multiple organisations and individuals.

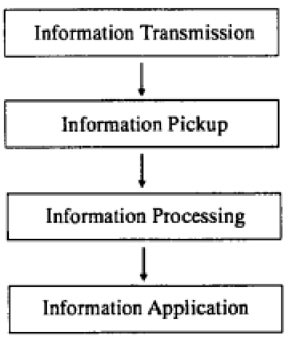


Figure 4.4: Knowledge utilisation as a stepped process

Source: Rich (1991:329)

Initially, the *information transmission* step is seen as the 'trigger' step for knowledge utilisation, where information is created or existing information is disseminated (Rich, 1991). Subsequently, the information is retrieved or received by a user from a databank or passed on in person through a discussion in the *information pickup* step. In this step, it is essential that the information be received. *Information processing* involves several sub-processes, whereby the user processes the information to ensure that user understand it and cognitively test it against the user's own intuition, assumptions, validity and reliability and then transforming it into a usable form to the preference of the user. The final step involves *the decision to apply or not to apply* the information whereby utilisation and non-utilisation are equally significant.

Rich (1991:329) also provides some insight into research impact, and argues that impact can be thought of as "a decision or action taken on the basis of (influenced by) research results", with the critical assumption that a specific decision can be *attributed* to specific data or information and that such information plays a key role in reaching decisions. Implicit in this assumption is that bits or clusters of knowledge can be traced through the organisation, from the point where it entered the organisation, to the point where it influenced a decision. Causal links can be made, if all factors, which relate to the decision, are known, and also the weighting a user places on these factors, and it is assumed, that such a user is fully aware of the discrete role the information plays in making a decision (Rich, 1991:330).

Alternatively, Rich (1991) argues that a decision-making process can be built up through interviews, and rely on the user's account of how specific information had an influence on the decision-making process.

In documenting the use of research-based knowledge, Rich (1991:330) concluded that researchers made use of in input/output model by taking a deterministic view of how knowledge that is gained through research, is disseminated and adopted, and that:

a) information can be traced from the point where it enters the organisation, to the point where an action is taken based on or influenced by the information;
b) on the information side, the impact can be measured relative to a piece or cluster of information; and
c) on the user side, it is possible to assess the impact or influence the information or cluster of information has on the behaviour of the individual to solve the problem.

Rich (1991) however states that such a traditional input/output model is not based on a realistic view of how societal problems are solved. He further highlights that it also does not accurately reflect how information enters the decision-making process in that decisions comprise multiple events, which occur longitudinally so that it is virtually impossible to understand a decision without taking into account the process of events, which led to the decision being taken. Rich (1991:331) then concludes that, as presented by Weiss and Bucuvalas (1980), it is almost impossible to predict when and where a particular knowledge input will have an effect on a policy decision, as multiple effects or inputs might have an effect, which is difficult to trace. Further, the input/output approach requires an analyst to attribute an action to the use of specific data or information and forces an analyst to find connections, even though some use and application might not be tied to a specific event.

Research impact assessments can be conducted either *ex ante* (i.e. prior to the research) to assess the potential significance and used to evaluate what the R&D project aims to do, or *ex post* (i.e. once the research has been completed) in order to measure the final outcome and performance of the project (Bulathsinhala, 2014). Moreover, literature often focuses on *ex-post* evaluation of public R&D projects (Chiesa, Frattini, Lazzarotti & Manzini, 2009; Kimura, 2010; Lee, Son & Om, 1996; Sakakibara, 1997), or *ex-post* evaluation at programme level (Arnold, Clark & Muscio, 2005; Blumstein, 2010; Georghiou & Roessner, 2000; Hobday, 1988; Ormala & Vonortas, 2005; Vine, 2008).

In comparison, less *ex-ante* evaluations have been carried out possibly due to the difficulty in quantitatively measuring what a project will do as opposed to quantitatively measuring *ex post*, the impact a project has had (Bulathsinhala, 2014). In addition, Bulathsinhala states that *ex-ante* evaluations are often used as an internal process, with a smaller audience than in the case of *ex-post* evaluations, thus adding to the difficulties in undertaking *ex-ante* evaluations as opposed to *ex-post* evaluations of R&D projects.

Interesting, however, that *ex-ante* evaluation frameworks, as presented by Roper, Hewitt-Dundas and Love (2004), argue that the knowledge base derived from *ex-post* evaluations of publicly supported R&D projects, is now providing sufficient evidence to enable *ex-ante* judgements on the likely benefits at regional level of such publicly supported R&D projects. One could argue that as this body of knowledge of *ex-post* evaluations grows a relative increase in *ex-ante* evaluations could be expected.

4.5.1 Challenges in linking research to research impacts

Various challenges have been identified in understanding the benefit of research. Some challenges are the establishment of attribution, the timing when an evaluation should take place, how to capture the duration of the research impact, establishing the reliability of information from key information interviews, and the identification of methods in order to capture as many benefits as possible (Bell, Shaw & Boaz, 2011). Some of these challenges are discussed in more detail.

4.5.1.1 Attribution, additionality and time lag

In measuring the benefit of scientific research, the question will always be asked whether the research output is really the key driver for the eventual impact, referred to as *attribution* (Boaz et al., 2009; Hargreaves, 2009; Molas-Gallart et al., 2002; Molas-Gallart & Tang, 2011). This has led to some studies preferring to use language that focuses on influence of research rather than impact (Boaz et al., 2009) and researchers such as Buxton (2011) affirming that "any impact is the product of the whole R&D system and not exclusively produced by the original researcher" (Buxton, 2011:260) and impact could be made through a series of "productive interactions" (Spaapen & Van Drooge, 2011:212). Moreover, questions will be asked on how the contribution of the research compares to that of other drivers referred to as *additionality*, (Davies et al., 2005:17), and whether the same benefits would be achieved without the research programme (Klautzer et al., 2011). Bell et al. (2011) provide some mitigating arguments, which include the establishment of counterfactuals, and asking key informants about the outcomes they would have expected without the input of the research. In addition, Bell et al. (2011) argue the adoption of demand-side approaches to impact evaluation (as opposed to supply-side approaches) and using major policy events to work retrospectively to establish influences, institutionalise impact evaluation processes, and ensure that staff take the responsibility to record outputs, dissemination efforts and known policy responses, which directly relate to the research. Of importance though, when institutionalising impact evaluation processes, is the risk of adding administrative burdens on staff (Wooding et al., 2007).

Moreover, a challenge exists whereby the ability to quantify and establish attribution reduces over *time* (Boaz et al., 2009). When research findings are published as outputs in the form of reports and/or articles, initial, intermediate and final outcomes could take quite a while following the initial research output, with a decrease in the ability to track attribution as evident in Figure 4.5.

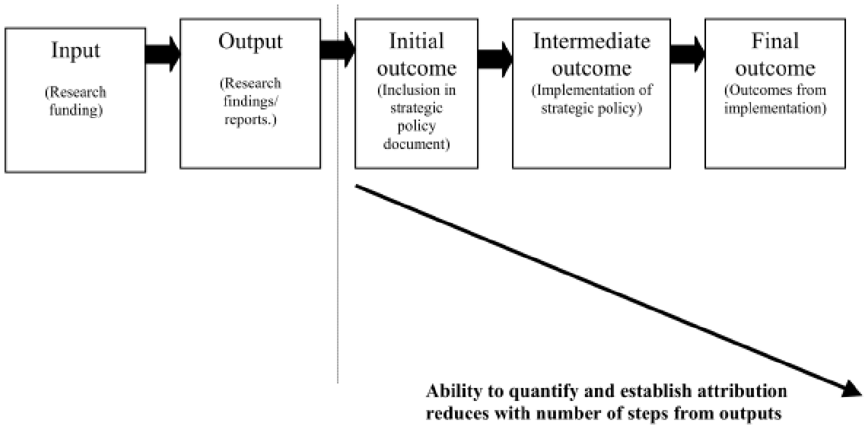


Figure 4.5: Losing attribution of research benefit over time

Source: Boaz et al. (2009)

4.5.1.2 Timing of assessments

During the research impact evaluation process, researchers often express concern relating to the timescale in which the benefits from the research occurs (Buxton, 2011). If the evaluation of the benefit of research is undertaken too early after the conclusion of the research, the impact of the research might not have occurred yet, or if the evaluation is undertaken too late, some benefits might have occurred without a lasting effect. The challenge lies in capturing the duration of the research impact (Bell et al., 2011). As a possible solution, a two-stage evaluation process could be undertaken, with the measurement of benefits shortly after the project completion (identifying short-term indicators, according to Buxton [2011]), and another later when the intended benefits should emerge. This suggestion is in line with Guinea et al. (2015) who propose, as part of impact-orientated monitoring (IOM) tools, that coordinators' surveys, end users' opinion surveys and/or assessment tools (scoring matrices) be undertaken in the middle of the project (for projects lasting four or more years), at the end of the project, or three years after the project.

4.6 Conclusion

This chapter reviewed literature in the field of knowledge utilisation, and specifically as it relates to knowledge for policy. Here it is evident that various models, frameworks and theories have been developed. The use of research knowledge can be categorised as *instrumental use,* which is in a specific or direct manner, or *conceptual use,* which is typically the most common use and over a longer period. Moreover, research knowledge can be used in a *symbolic* manner where decision-makers commission a researcher to support a predetermined position or to pressure him or her to act on a specific issue or to legitimise him or her to substantiate preferred policy issues. Lastly, knowledge use can be categorised as *process use,* which results through the involvement of researchers and decision-makers in experiential learning and reflection in research.

Various researchers (such as Caplan [1979] and Rich [1991]) further refer to the existence of a cultural gap between researchers and decision-makers often referred to as the two-communities'. Moreover, the cultural gap between researchers and decision-makers results in low levels of research uptake. Factors, which contribute towards the gap, are distrust, competing and alternative reward systems, alternative language and jargon, different time frames in addressing issues and a misalignment between the priorities of researchers and those of decision-makers.

To bridge the cultural gap, various researchers have presented theories, models and frameworks, such as proposing task forces, centres, commissions, councils, legislative committees, large consulting firms and boutique consultants, interest groups, associations and think-tanks as they relate to the systems and environments required for research uptake. Moreover, the positive roles and actions of information specialists, change agents (individuals or internal/external groups) who often act in coalition with each other and with decision-makers and researchers, are further important to effect research uptake. Such efforts should typically form part of a strategy for research uptake. In addition, research should be presented in a 'language' and format that are appealing to decision-makers, which implies that researchers should add additional resources to their research in order to support research uptake.

Moreover, with a new production of knowledge, or Mode 2, coming to the fore in the early 1990s, ideas relating to multi-, inter-, and transdisciplinary research have subsequently gained momentum and innovation *ecosystems* in the form of networks are now established. Here, a variety of stakeholders, which include researchers, industry, policymakers and a variety of societal stakeholders, come together to co-create knowledge; thus, contributing to a case where researchers not only have to deal with only two communities, but a variety of networks and communities.

In addition, scholars, such as Greenhalgh et al. (2003) and Greenhalgh et al. (2004) suggest that research uptake should be supported by planned or deliberate dissemination efforts, or the diffusion of knowledge, which is passive and could take much longer. Scholars such as Knott and Wildavsky (1980) argue that various levels or stages of utilisation exist, and that researchers should time their dissemination efforts in accordance with a strategy, as again, resources will be required to disseminate research for eventual uptake. All these efforts should be undertaken in an environment that encourages mutual trust, openness and co-ordination, which are supported by access and proximity to resources.

There are various challenges associated with linking the benefits from research to activities from a specific research project, and is referred to as *attribution* and *additionality*. With many factors in the whole R&D system influencing research impact, some studies prefer language that focusses on the influence of research, rather than impact. In addition, the ability to quantify and establish attribution reduces over *time*, making the timing of assessments important; therefore, it is recommended that continuous assessments be undertaken in the middle of a project, at the end of a project and a few years after the project, to identify the outcomes from the research in terms of the benefits of the research.

At this stage, it is pertinent to consider again the HERG Payback Framework, which has been chosen as the conceptual framework for this study (refer to Chapter 2 for a detailed discussion), and to reflect further on the aspects highlighted in the literature review on knowledge for policy. As reference, the HERG Payback Framework and how it relates to the objectives of the study are presented in Figure 4.6. Here it is evident that primary outputs from research (in stage 3) are disseminated to the reservoir of knowledge, and the broader political, professional, industrial and society ecosystem where policymaking takes place and products are co-created (stage 4) and further adopted by practitioners and the public (stage 5).

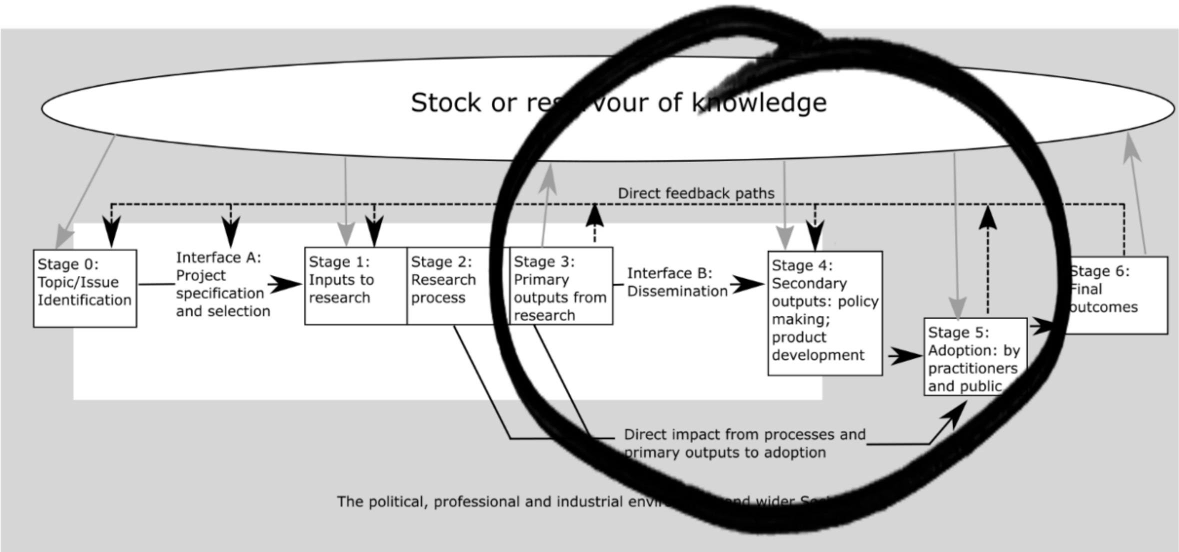


Figure 4.6: The HERG Payback Framework and the objectives of this study

Source: Adapted from Hanney et al. (2004)

With this better understanding of the various approaches to knowledge utilisation and research impact assessments, questions can now be asked about the WARFSA programme as it related to the innovation *ecosystem*, and specifically the role of policymakers, practitioners and other stakeholders during and after the research projects, the dissemination of the research findings, the adoption of research findings by policymakers and practitioners, and the role of intermediaries and knowledge brokers. This will be reflected in Chapter 12 of this thesis, once a better understanding of the primary outputs of water research in the SADC region has been established, not only in general (Chapters 7 to 10), but also in the WARFSA programme specifically (Chapter 11).

Chapter 5
RESEARCH METHODOLOGY

5.1 Introduction

This chapter discusses the methodologies used to compile the quantitative data for the bibliometric analysis as presented in various chapters of this thesis. In addition, the qualitative methods used to assess policy aspects resulting from research projects of the WARFSA are also discussed.

5.2 Data collection techniques for the HERG Payback Framework dimensions

To operationalise the HERG Payback Framework (Donovan & Hanney, 2011), quantitative and qualitative data collection and analysis techniques were identified for each of the research impact dimensions, such as science, policy, economic and social benefits (Table 5.1). These techniques comprised bibliometric methods, documentary reviews, personal interviews, user surveys and cross-case analysis of selected case studies, and were applied to collect data.

It has been argued that such a broad mixed-method could provide limitations and add many resources to a research project (Greenhalgh et al., 2016; Searles et al., 2016). Some have adapted the Framework for this reason (see for example European Commission, 2013). Moreover, various research benefits manifest at various stages of the research process as highlighted in the logical model of the HERG Payback Framework (Donovan & Hanney, 2011). From Table 5.1, it is evident that science impacts typically manifest in Stage 3 in the form of primary research outputs, the policy benefits as secondary outputs in Stage 4, and economic, and social benefits manifesting as final outcomes in Stage 6 of the logic model.

Table 5.1: Data collection techniques of the HERG Payback Framework dimensions and associated stages of research impact

Impact sphere	Category/Dimension	Operational definition	Associated stage as per logic model	Data collection and analysis techniques
1. Science impact	1.1 Knowledge and development products and techniques	• Peer-reviewed journal articles • Conference presentations and proceedings, books, book chapters, research reports • Master's and PhD dissertations • Computer software • Development of theoretical frameworks and computer models	• Primary outputs - stage 3	• Bibliometric methods (citation analysis) • Interviews with researchers • Altmetric methods

Impact sphere	Category/Dimension	Operational definition	Associated stage as per logic model	Data collection and analysis techniques
		• Publications in the World Wide Web, such as blogs and social media platforms		
	1.2 Benefits to future research and research use	• Better targeting of future research • Development of research skills, personal and overall research capacity • A critical capacity to absorb and utilise appropriately existing research, including that from overseas • Staff development and educational benefits • The influence research has had on obtaining future research and funding	• Primary outputs stage 3	• Documentary review including analysis of personal CVs • Personal interviews
2. Policy impact	2.1 Benefits from informing policy	• Improved information bases (as developed as knowledge products) for political and executive decisions Development of teaching and training material	• Secondary outputs stage 4	• Documentary review and interviews • Altmetrics
3. Economic impact	3.1 Broader economic benefits	• Benefits from commercial exploitation of innovations arising from R&D	• Final outcomes stage 6	• Personal interviews • Selected case studies For this dimension, statistics would also be important
4. **Social impact**	5.1 Benefits to society	• Improved health as a result of better techniques	• Final outcomes stage 6	• Personal interviews • Selected case studies • Relevant statistics would be used

Source: Adapted from Donovan and Hanney (2011)

Given the focus and scope of this study on the contribution of the WARFSA to knowledge production and informing policy (Stages 3 and 4 of the logic model of the HERG Payback Framework), bibliometric techniques, personal interviews and documentary reviews assisted in identifying benefits related to the scientific impact of research. Altmetrics further assists in identifying research use beyond the traditional citation databases; however, this was beyond the scope of the present study, given that these developments have occurred most recently, and could be considered in future research. In terms of identifying the influence of research on policy formulation, documentary review and interviews were used. Again, Altmetric data could provide information on the use of specific research to influence policy decisions but fell outside the scope of the present study.

5.3 Defining the quantitative datasets

Throughout the study, various quantitative datasets were compiled and analysed, and these are presented in this thesis. The following section presents the methodologies used to compile the datasets.

5.3.1 Bibliometric datasets

It is relevant to mention at this stage that bibliometric data were compiled for the period between 1980 and 2016. This is not insignificant, given the historic background and increasing coherence among Southern African countries over this time, with first the establishment of the SADCC (Southern African Development Coordination Conference) in 1980. At that time, integrated water management, although limited, played an important role in bringing countries together, as evident through the implementation of the ZACPLAN (Zambezi River System Action Plan) in the mid-1980s affecting the eight riparian states of the Zambezi River, with the ZACPLAN later providing the basis for negotiations throughout the 1990s in the establishment of the Zambezi Watercourse Commission (ZAMCOM) in 2004 (De Almeida, 2004). With South Africa emerging from isolation in the early 1990s, and with an ever-increasing co-ordination, the SADC was established out of the SADCC in 1992 (see Tsie, 1996). Moreover, a greater awareness and implementation of Integrated Water Resource Management (IWRM) surfaced in the early 1990s in the SADC region, and is well documented (see for example Claassen, 2013; Movik, Mehta & Manzungu, 2016). As the implementation of IWRM grew in the SADC region, so too did the need for water research and capacity development, eventually leading to the establishment of the Water Research Fund for Southern Africa (WARFSA) and the WaterNet master's degree programme in late 1990s and early 2000s (Van der Zaag, 2005; Wright, Savenije & Van der Zaag, 2001), putting water research in the region high on the political agenda. Subsequently, water research and capacity development have been specifically articulated in the various versions of the SADC Regional Strategic Action Plans on integrated water resource management and development (commonly referred to as the RSAPs) since 1999, with the latest RSAP IV focussing on the period 2016 to 2021 (see SADC, 2016).

Moreover, it is important to keep in mind that the WARFSA programme was implemented as a SADC-regional initiative, which further made it imperative to compare bibliometric data on African and global water research and publications. Working within the Centre for Research on Evaluation, Science and Technology (CREST), primary data captured in the Clarivate Analytics™ Web of Science™ Core collection database,[6] was used, with a stepped approach followed to identify citation data for the present study.

Step 1: all publications, across all research areas in the Clarivate Analytics™ Web of Science™ Core collection database were identified for the period 1980 to 2016, with publications including 'all languages' and 'all document types'.

Step 2: Making use of the global dataset, all African countries were identified, resulting in a query: COUNTRIES/TERRITORIES (SOUTH AFRICA or EGYPT or NIGERIA or MOROCCO or ALGERIA or KENYA or TANZANIA or ETHIOPIA or UGANDA or CAMEROON or GHANA or ZIMBABWE or SENEGAL or SUDAN or MALAWI or ZAMBIA or BOTSWANA or BURKINA FASO or LIBYA or BENIN or MALI or ZAIRE or MADAGASCAR or GABON or MOZAMBIQUE or GAMBIA or NAMIBIA or NIGER or MAURITIUS or RWANDA or CONGO or IVORY COAST or SIERRA LEONE or SWAZILAND or GUINEA or CENT AFR REPUBL or BURUNDI or ANGOLA or LESOTHO or GUINEA BISSAU or SEYCHELLES or CONGO PEOPL REP or LIBERIA or SOMALIA or UPPER VOLTA or TRANSKEI or DJIBOUTI or CISKEI or EQUAT GUINEA or BOPHUTHATSWANA or DEM REP CONGO or RHODESIA or REP CONGO or SAO TOME PRIN or ZIMBABWE RHODES or VENDA or SOUTH SUDAN) and WEB OF SCIENCE Categories (Water Resources).

Step 3: In addition, all SADC countries were identified, resulting in a query: countries/territories (SOUTH AFRICA or TANZANIA or ZIMBABWE or MALAWI or ZAMBIA or BOTSWANA or ZAIRE or MADAGASCAR or MOZAMBIQUE or NAMIBIA or MAURITIUS or SWAZILAND or ANGOLA or LESOTHO or SEYCHELLES or TRANSKEI or CISKEI or BOPHUTHATSWANA or DEM REP CONGO or RHODESIA or ZIMBABWE RHODES or VENDA) and WEB OF SCIENCE categories (water resources).

Step 4: In addition, publications for South Africa were identified, resulting in a query: countries/territories (SOUTH AFRICA or TRANSKEI or CISKEI or BOPHUTHATSWANA or VENDA) and WEB OF SCIENCE categories (water resources).

Step 6: In addition, all SADC countries, which exclude South Africa, were identified, resulting in the query: countries/territories (TANZANIA or ZIMBABWE or MALAWI or ZAMBIA or

[6] The Clarivate Analytics™ Web of Science™ Core collection database includes the following citation indexes: Science Citation Index Expanded (SCI-EXPANDED): 1970–present; Social Sciences Citation Index (SSCI):1970–present; Arts & Humanities Citation Index (A&HCI): 1975–present; Conference Proceedings Citation Index – Science (CPCI-S): 1990–present; Conference Proceedings Citation Index – Social Science & Humanities (CPCI-SSH): 1990–present; Book Citation Index – Science (BKCI-S): 2005–present; Book Citation Index – Social Sciences & Humanities (BKCI-SSH): 2005–present; Web of Science Core Collection: Chemical Indexes Index Chemicus (IC): 1993–present.

BOTSWANA or ZAIRE or MADAGASCAR or MOZAMBIQUE or NAMIBIA or MAURITIUS or SWAZILAND or ANGOLA or LESOTHO or SEYCHELLES or DEM REP CONGO or RHODESIA or ZIMBABWE RHODES) and WEB OF SCIENCE CATEGORIES (WATER RESOURCES).

One of the major challenges in defining ‘water research’, is that it is not a well-defined research field, and can be classified as interdisciplinary in character (Pouris, 2013). In terms of bibliometric studies, the interdisciplinary nature of water research could provide challenges in extracting citation data from the Clarivate Analytics™ Web of Science™. However, Clarivate Analytics™ Web of Science™ provides a single category for ‘water resources’ which accounts for the ‘core’ journals in the field of water research, which further accounts for the most important and highest impact literature on water research (Pouris, 2013). Refer to Annexure B for a list of journals reflected in the Clarivate Analytics™ Science Citation Index categorised under the ‘water resources’ category. Along with the global, African and SADC datasets, publications that are categorised as ‘water resources’ in the Clarivate Analytics™ Web of Science™ Core collection database were identified.

Step 7: When calculating total publications and water research publications in the SADC region, records for specific countries were calculated as follows:

1. for Zimbabwe, citation data for Rhodesia and Zimbabwe Rhodes were included in Zimbabwe;
2. for South Africa, citation data for Ciskei, Transkei, Bophuthatswana and Venda were included in South Africa;
3. for the Democratic Republic of Congo, the Clarivate Analytics™ Web of Science™ Core collection database indicates publication data for ‘DEM REP CONGO’, ‘REP CONGO’, ‘CONGO’ and ‘ZAIRE’. As the Republic of Congo is not within the SADC region, publication data for ‘DEM REP CONGO’ and ‘ZAIRE’ were used for this study. Publication data coded as ‘CONGO’ were not used for this study, as it could reflect either the Democratic Republic of Congo or the Republic of Congo, the latter not part of SADC.

These datasets were used in comparing the share of water research in SADC with African and global research output, and to present the relative activity SADC countries devote to water research as a share of total publications (Chapter 7).

In total, 5 729 water research publications were identified from the 15 countries in the SADC region representing publications where any author, and not only the lead author of a water research publication, was affiliated with a university or research institution from the SADC region. During the study, it further became evident that some Southern African countries produce a large portion of water research, when compared to the overall research output in the countries, with South Africa publishing the most water research material in the region.

Therefore, part B of the study was further divided into three chapters focussing on various angles of water research in the SADC region:

- Chapter 8: Water publications by SADC countries;
- Chapter 9: Water publications from South Africa; and
- Chapter 10: Water publications of SADC countries where South Africa is excluded (for this study, referred to as SADC-ExSA countries).

5.3.2 Bibliometric indicators

The increased application of bibliometric analyses (*bibliometrics*), involving the quantitative analysis of publications and citation data to trace literature, provides insight into the scientific use of the research outputs. Bibliometrics is further used to assess scientific use and the research productivity of individual researchers, in relation to their institutions, their subject areas, collaborations with other researchers and funding agencies who support specific research areas. In the next section, aspects of bibliometric analysis will be discussed in more detail, such as citation counts, citation rate, journal impact factor, altmetrics and *h*-index which guided the bibliometric analysis of water research in the SADC region in the chapters that follow. In addition, the aim of the following section is not to provide a detailed review of citation impact indicators (rather refer to Waltman [2016]). Mingers & Leydesdorff (2015) further provide a detailed review of the theory and practice in scientometrics.

5.3.2.1 Publication and citation analysis

Over the years, international citation index databases, such as the Clarivate Analytics (CA) Web of Science™, and the Elsevier™ Scopus databases have been developed whereby the citation information of research articles are collected, and which provide a source of data for the bibliometric analysis of publication and citation data. At its most basic level, the number of *citation counts* over the lifespan of an individual article provides an indication of its scientific relevance and a specific research topic, and is often indicated where the calculation includes and/or excludes self-citations. In addition, when one considers a set of articles, the *citation rate* provides an indication of how many times the average article in the set of articles had been cited, irrespective of a certain year. An example would be how many times the average water research article published between 1980 and 2016 from SADC countries had been cited – one of the questions addressed in this study. In addition, a set of articles could be analysed with the *citation score* addressing the question *How many time have certain articles in a specific year been cited?*

To further consider differences between researchers, journals or institutions across research fields, citation counts are normalised, especially considering time periods as the number of citations always increases over time (Leydesdorff, Bornmann, Mutz, & Opthof, 2011; Waltman & van Eck, 2013). In this study, the *mean normalised citation score* (MNCS) is used, which is a further development of the crown indicator used by the Centre for Science and Technology Studies (CWTS) of Leiden University (Waltman, van Eck, van Leeuwen, Visser & van Raan (2011). In essence, the MNCS indicator normalizes citation scores of articles, letters and reviews, and adjusts each citation count by considering the average citation scores for the world in its field and year, and where the world average is always 1 (Thelwall, 2017, Waltman et al. 2011). By then further calculating the arithmetic mean of the normalised citation counts, the MNCS is determined (Waltman et al., 2011). When further calculating the MNCS, all fields are considered to have the same weight, regardless of their average number of citations per publication. In addition, the MNCS indicator is size independent, and intended to measure the average performance of a set of publications. Finally, the MNCS calculation treats publications from different fields equally, and consider that publications could belong to more than one, and overlapping research field, in which case articles and citations are weighted (Waltman et al., 2011). To calculate the MNCS indicator for a unit, CREST first calculates the normalized citation score of each publication unit. The normalized citation score of a publication equals the ratio of the actual to the expected number of citations of the publication, where the expected number of citations is defined as the average number of citations of all publications in WoS that belong to the same field and that have the same publication year and the same document type. The field (or the fields) to which a publication belongs is determined by the WoS subject categories of the journal in which the publication has appeared. The MNCS indicator is obtained by averaging the normalized citation scores of all publications of a unit.

In addition to the abovementioned citation scores, one of the most popular products of bibliometrics is the *impact factor*, which is regularly published in journal citation reports (JCR) (Glänzel & Moed, 2002). The impact factor considers the number of citations a set of articles in a journal, or a specific set of articles have received in a specific year, divided by the total number of articles published in the same journal or a set of articles published during the preceding two years. The use of the impact factor dates back to 1955, when Eugene Garfield suggested that reference counting could be used as a measure of ‘impact’, with the publication of the article ‘*Citation indexes for science; a new dimension in documentation through association of ideas’*. This was followed in 1963 with the publication of the 1961 science citation index (SCI) where the term ‘impact factor’ was first used (Garfield, 1996), describing how the impact factor can be used as a citation-based measure, to indicate significance and the performance of a scientific journal as the journal impact factor (Garfield, 1964; 1972; 1998a; 1998b; 2006; Persson, 2000). Today, the impact factor and journal impact factor (JIF) is widely used within the science community. But the impact factor is not without its limitations, such as methodological challenges, which could be addressed through additional, multi-dimensional measures (Glänzel & Moed, 2002). Garfield himself warned that using the journal's average citation impact instead of the actual article impact, is tantamount to grading by the prestige of the journal involved, and that evaluation at faculty level is much more important where it affects people's careers, when he said, "[i]mpact numbers should not be used as surrogates except in unusual circumstances" (Garfield, 1996:413).

With the further development of *altmetrics* (Almind & Ingwersen, 1997), cited references in webometric databases, such as Google Scholar and online platforms such as Altmetric (www.altmetric.com) and Plum Analytics[7] (www.plumanalytics.com), are useful to measure the relevance of research on alternative publishing platforms. These altmetric tools scan online media platforms such as blogs, Wikipedia, news sites and social media platforms, such as Twitter or Facebook and provide information on the attention a scientific output receives. In the case of Plum Analytics, information is further drawn from traditional citation indexes, such as Scopus, providing a dynamic data visualisation display on the use of the research. Some have however cautioned that altmetrics is still in its relative infancy and should be used with caution (Aguillo, 2012; Garfield, 2006; Wouters & Costas, 2012), and that disadvantages and uncertainty exist in terms of the commercialisation of research portals, data quality, missing evidence and data manipulation (Bornmann, 2014). However, as seen by the developments of platforms such as Plum Analytics and the recent integration of such a platform into Elsevier, these platforms start providing insightful information on the use of research beyond the citation indexes. In terms of this study, and given the most recent developments of altmetrics, altmetric scores were not included in the study, and could be catered for in future research.

At individual level, the computation of the Hirsch index (see Hirsch, 2005) or *h-index* provides an indication of the "importance, significant and broad impact of a scientist's cumulative research contribution" of a specific researcher, and could be used to provide a measure to compare different researchers (Hirsch, 2005:16572). The *h*-index provides a single numerical measure and includes both quantity and visibility of the research work of a researcher (Egghe, 2006; Egghe & Rousseau, 2006). In his 2005 article, Hirsch defines the *h*-index as "a scientist has index *h* if *h* of his or her *Np* papers [Number of papers] have at least *h* citations each and the other (*Np*- *h*) papers have fewer than ≤ *h* citations each". In other words, where a scientist has an *h*-index of 20, such scientist has published 20 articles that each had at least 20 citations. Figure 5.1 illustrates the difference between two researchers who had published the same number of articles, but with a difference in the number of highly cited articles, and which resulted in a higher *h*-index.

[7] Plum Analytics joined Elsevier in 2017 (Elsevier, 2017)

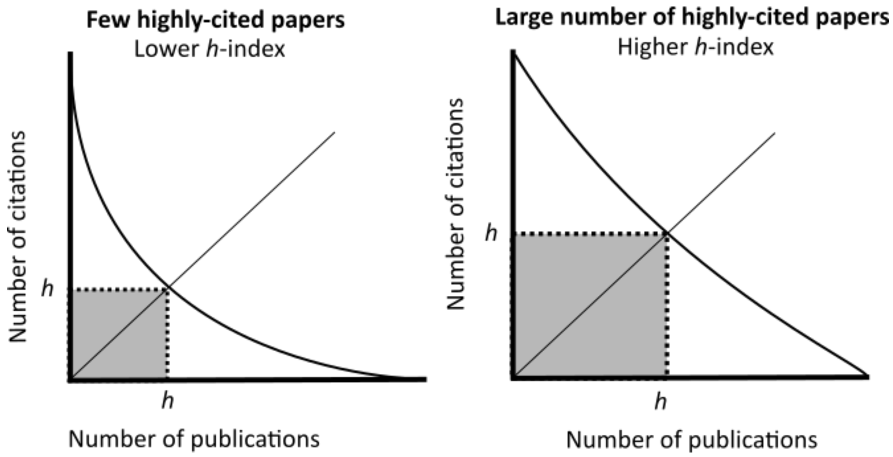


Figure 5.1: Variation in *h*-index authors with the same number of publications

Source: Author's own compilation

Over the years, the *h*-index has become a widely used indicator in the scientific community, although it has not been without criticism and proposed improvements and variants. In a 2011 study, as many as 37 different variants of the *h*-index were identified (Bornmann, Mutz, Hug & Daniel, 2011). Following the original *h*-index, Hirsch (2010) proposed the index ħ ('hbar'), which builds on the *h*-index, but now takes into account the effect of multiple authorship. Hirsch (2010) argues that in cases where researchers collaborate with researchers with a high *h*-index, such co-authors could increase the author's *h*-index, and should be eliminated from calculating the ħ index. There have however been a few examples where the ħ-index had been calculated.

Reflecting on the *h*-index (Hirsch & Buela-Casal, 2014), Hirsch argues that much of the criticism against the *h*-index is unfounded, and that the main limitation of the *h*-index is that it does not discriminate between researchers who publish alone or in small research groups, versus researchers who publish articles with many co-authors, which leads to higher *h*-indexes. According to Hirsch (Hirsch & Buela-Casal, 2014), such higher *h*-indexes, which result from articles with a large number of co-authors, does not necessarily reflect higher merit. Moreover, Hirsch argues that the *h*-indexes of researchers in the Natural Sciences are higher than those in the Social Sciences and in Arts and Humanities. Many factors influence this phenomenon, where it is found that researchers from the Social Sciences and Humanities more frequently publish books rather than articles, with the citations of books not contributing towards the *h*-index. Moreover, in the case of Natural Science, it was found that researchers lead larger research groups and co-author more articles from the research groups, which then in turn lead to higher *h*-indexes than Social Sciences and Humanities. Articles in disciplines that tend to have a higher number of references, such as in the Natural Sciences, tend to lead to higher *h*-indexes. In addition, in some research fields, certain topics attract greater attention than others, which often leads to sudden growth in *h*-indexes of the researcher in those topics. Another factor which influences a higher *h*-index is the language in which research is published, with English articles being cited more often; thus, leading to a high *h*-index. Finally, Hirsch and Buela-Casal (2014:164) conclude that the *h*-index is useful as an "objective" element in comparing different researchers with each other, and that it should supplement other elements such as "prestige", and the opinion of peers in the different research fields. Other elements could include the institution to which the researcher belongs or the journal in which he or she publishes – factors which do not directly influence the *h*-index.

5.3.2.2 Activity index

The activity index (AI) gives an indication of the relative effort a country devotes to a research field (Frame, 1977; Schubert & Braun, 1986), and is calculated as:

$$AI = \frac{\text{a country's share in the world's publication output (in a particular research field)}}{\text{a country share of the world's publication output in all science fields}}$$

An index of above 1 would indicate an effort above the world average, with an index below 1 indicating effort below world average. Where the AI is equal to 1, it would indicate that the effort of that country is corresponding with the world effort (Schubert & Braun, 1986). Related to this study, Pouris (2010) undertook a scientometric assessment of research from SADC countries between 1994 and 2008 (which included the AI scores of 22 disciplines of 12 of the most prolific SADC countries), and Pouris and Ho (2013) presented the AI scores of various research fields from African countries between 2007 and 2011. In the case of the present study, the AI of SADC countries was calculated for their relative effort in water research, and is presented in Chapter 7.

Over the years, bibliometric studies have been undertaken on science production emanating from researchers affiliated with universities and research institutions from the African continent, addressing some of the aspects discussed above. The next section gives an overview of water research publications in the SADC region.

5.3.3 An analysis of knowledge produced from research projects associated with the WARFSA programme

Chapter 11 of this study presents an analysis of knowledge produced in research projects associated with the Water Research Fund for Southern Africa (WARFSA) for the period 1999 to 2016.

From the outset, it was clear that limited documentation was available on projects associated with Phases I and II of the WARFSA initiative. This was partly due to the fact that approximately 10 years had passed since the programme had come to an end (in 2007), and some projects had been conducted between 8 and 15 years ago. Although project reports were submitted to the WARFSA board, few hard copy files are available, and electronic copies of documentation were limited to personal archives of individuals involved in the management of the WARFSA programme or as board members. Former programme managers and WARFSA board members were contacted, in order to obtain as much information as possible. Through this process, some documents such as minutes, agenda items and correspondence related to research projects could be compiled.

Given these limitations, meta-data were compiled from WARFSA board meeting reports and project reports. In total, 78 research projects were identified with data, which included project numbers, project titles, names and contact information of the principle investigator (PI). Refer to Annexure C, for a list of WARFSA-funded research projects, which were used for this study. Eventually contact information was found to be outdated for many researchers. Where available, e-mail information was updated from WaterNet membership lists and the online social media platform LinkedIn (http://www.linkedin.com). The contact details of 84 researchers were obtained through this process. For all project PIs, e-mails were sent requesting information, such as the objective of the study, reference to any research outputs, such as journal articles, policy briefs, book chapters or project progress reports. Information on collaborators and their contact details was also requested. Reminders for the request for information were sent two weeks and four weeks after the initial request. The response rate was very low, probably due to the time lag since the projects had taken place. Where information was provided, meta-data were captured.

Following the initial data collection from available electronic records and project PIs, the database was further populated making use of Google Search and Google Scholar. Search criteria included '[PI surname]', '[Research project title]', '[PI surname] and/or WARFSA'. Once a potential research project had been identified, the content of the research outputs was scrutinised for the keyword 'WARFSA', as authors often acknowledged the support from the WARFSA programme in the articles and documents published, thus addressing the issue of attribution (Hargreaves, 2009; Molas-Gallart et al., 2002; Molas-Gallart & Tang, 2011). This was discussed in detail in Chapter 4. In some cases, through personal contacts with researchers, specific research outputs were also identified, which related to the WARFSA programme. Through this process, the 230 research outputs were identified and attributed to the WARFSA Phases I and II. In addition, the 230 research outputs were verified against International citation indexes, which included the Clarivate Analytics™ Web of Science™ Core collection database[8] (WoS) and ScienceDirect™ database, resulting in 84 research outputs (34%) being verified in these citation indexes, which were used for publishing trends and citation analysis in this study.

5.4 Defining the qualitative datasets

Part C of this study presents a case study analysis of knowledge produced and the policy and practitioner aspects resulting from the WARFSA programme. As presented in Table 5.2, bibliometric data analysis techniques were used to assess the knowledge produced from research projects funded through the WARFSA programme. In addition, personal interviews and qualitative data analysis techniques were used to assess policy and practitioner aspects resulting from the WARFSA programme.

Table 5.2: Data collection techniques to assess knowledge produced and policy and practitioner aspects of WARFSA-funded research

Category/Dimension	**Operational definition**	**Data collection and analysis techniques**
Knowledge and innovation products	Peer-reviewed journal articles Conference presentations, books, book chapters, research reports	Bibliometric methods (citation analysis)
Benefits from informing policy and product development	Improved information bases for political and executive decisions Other political benefits from undertaking research Practitioner uptake of researcher and product development	Documentary review of available research reports and CVs Personal interviews Altmetrics

5.4.1 Policy and practitioner aspects evident form WARFSA-funded research projects

By making use of the mixed-methods approach, which included the assessment of meta-data in the projects, personal interviews and the coding and interpretation of transcribed interviews, a cross-case analysis of themes is presented with themes arising from the interviews.

Initially, potential projects along with the principal investigators (PIs) and associated researchers were identified, based on available documentation. However, as indicated in the previous sections, a document audit of the 78 research projects revealed that 57 projects had any relevant meta-data on projects, which included only 20 projects with progress reports. In

[8] The Clarivate Analytics™ Web of Science™ Core collection database included the following citation indexes: Science Citation Index Expanded (SCI-EXPANDED): 1970–present; Social Sciences Citation Index (SSCI):1970–present; Arts & Humanities Citation Index (A&HCI): 1975–present; Conference Proceedings Citation Index Science (CPCI-S): 1990–present; Conference Proceedings Citation Index Social Science & Humanities (CPCI-SSH): 1990–present; Book Citation Index Science (BKCI-S): 2005–present; Book Citation Index Social Sciences & Humanities (BKCI-SSH): 2005–present; Web of Science Core Collection: Chemical Indexes Index Chemicus (IC): 1993–present.

addition, 26 CVs of researchers were available, which were used in identifying projects which could be used for interviews. Meta-data further provided the e-mail addresses of the project PIs; however, these were fairly outdated, as the WARFSA programme implementation concluded more than ten years ago (in 2007). The e-mail addresses were updated with e-mail data obtained through the WaterNet secretariat, to which many of the researchers belong and with which they are associated. Initial e-mail contact was made with WARFSA project PIs, requesting further information, such as project reports, and further whether a preliminary indication could be provided of whether policy uptake resulted from their specific research. This assisted in identifying active e-mail addresses and, secondly, potential researchers who could be contacted to be interviewed.

Through a systematic process, the 20 research reports and 26 CVs were analysed, for any reporting on external stakeholder engagements during the project. Fortunately, the WARFSA programme required a specific section on stakeholder engagement to be reported on, which assisted in identifying potential candidates for interviews. This resulted in the identification of 29 project PIs who could be candidates for interviews. In addition, a WARFSA board member and a former programme manager were identified who were available for interviews to supplement questions related to the translation of research into policy and practice.

Since the WARFSA projects were undertaken more than 10 years ago (1999 to 2007), an interview schedule was developed consisting of two parts. Part 1 comprised questions relating to the project itself with the specific aim of ‘taking researchers back’ to the project and to refresh their memory on the specific project. The second part focussed on questions relating to the translation of the research project into policy and/or practice. Refer to Annexure D for the interview schedule.

In total, ten interviews were conducted, with eight interviews with the PIs from WARFSA-funded research projects, and additional interviews with one former WARFSA board member and one former WARFSA programme manager. Given the limited number of interviews, the full extent of ‘policy impact’ could not be determined, and for this reason, thematic areas were explored through a cross-case analysis of the interviews.

At the start of the interview, it was indicated to interviewees that the interview will not be anonymous, and that they had the option to opt-out and discontinue at any stage of the interview. Interviews were recorded, transcribed and code-assessed making use of the computer-assisted software ATLAS.ti software version 8.0.

5.4.1.1 Coding with ATLAS.ti

ATLAS.ti is a computer-aided qualitative data analysis software (CAQDAS) program and a tool which supports the process of qualitative data analysis (Friese, 2014) in order to assist in defining, categorising, explaining, exploring and mapping qualitative data (Ritchie & Spencer, 2002). From the transcribed interviews, cross-case themes were identified, which involved 'making judgements about meaning, about relevance and importance of issues, and about implicit connections between ideas'.

The ATLAS.ti computer software allows for the setting up and assigning of codes to segments of the transcribed interviews, which are of interest to the research objective (Friese, 2014). An initial coding was set up, which was based on the interview questions, to capture responses based on the questions presented during the interviews (Table 5.3). As initial questions focussed on the background to the projects, questions probed the role of the interviewees in the WARFSA programme and in the case of the research projects, the original impetus to the project: what influenced the research topic, the outcome of the research on subsequent research, and outputs which resulted from the research.

Table 5.3: Coding of interviews in ATLAS.ti

Background to the research project	**Policy and practitioner uptake**
Role of WARFSA: PI	Involvement in project selection: Yes
Role of WARFSA: Researcher	Involvement in project selection: No
Role of WARFSA: Board member	Assisting with the project: Yes
Role of WARFSA: Programme manager	Assisting with the project: No
Impetus: Society need	Disseminate of research
Impetus: Scientific curiosity	Direct citing of research: Yes
Impetus: Policy need	Direct citing of research: No
Influenced by: Own previous research	Citing of subsequent research: Yes
Influenced by: Other research	Citing of subsequent research: No
Subsequent research: Yes	Barriers to research uptake
Subsequent research: No	

Interviewees were offered anonymity at the beginning of the interviews, which they all declined, and for this reason, no anonymous codes were assigned for each coded segment during the analysis stage. The ATLAS.ti software program assigned a number to each coded segment, preceded by the document number. As transcribed interviews were loaded in three batches into the ATLAS.ti software program, a report of the coded segments thus reflects coded segments, followed by the interviewee code, the document number and coded segment number, for example (Turton 1:74)

Following the initial coding process, themes were identified based on the coded responses, with coded responses re-allocated in the cross-case themes for discussion. Themes comprised the involvement of practitioners and policymakers in the research projects; the dissemination and translation of research findings into policy and practice, and intermediaries and knowledge brokers.

5.5 Conclusion

The various research methods discussed here allowed for a systematic process to compile, analyse and assess quantitative and qualitative data throughout the study. As the WARFSA programme was but one initiative which contributed towards water research in the SADC region, an overview and sector analysis of knowledge production in the SADC water sector are initially presented (as Part A), which is followed by an analysis of knowledge production of the WARFSA-funded research, and policy and practitioner aspects related to the WARFSA programme, as Part C. Table 5.4 presents the research process, highlighting the aim of specific chapters.

Table 5.4: The research process of this study

Chapter	Aim of the chapter
Part B: SECTOR ANALYSIS AND KNOWLEDGE PRODUCTION IN THE SADC WATER SECTOR	
Chapter 6	Chapter 6 systematically presents the institutional landscape of the SADC water sector, with the aim to provide an overview of various water research programmes and network initiatives, international organisations, research and innovation units and societies, associations and academies in the SADC region
Chapter 7	Chapter 7 provides the context of knowledge production in the SADC region. It is important to present an overview of the knowledge production in the SADC water sector, as it relates to other African countries and globally. It became evident that 81% of all water research between 1980 and 2016 was produced by South African water researchers, and for this reason, a further analysis of publication and citation data were undertaken for SADC countries (Chapters 8), South Africa (Chapter 9) and other SADC countries, excluding South Africa in Chapter 10.
Chapter 8	Chapter 8 reports on an analysis of the publication and citation data of SADC countries, making use of bibliometric techniques. Data were analysed to present: • the research output in the SADC region and countries; • citation analysis of research articles; • the distribution of SADC water research articles in peer-reviewed journals; and • the organisations that are providing financial support for the research in the SADC region.

Chapter	Aim of the chapter
Chapter 9	As in the case of Chapter 8, Chapter 9 reports on an analysis of the publication and citation data of South African water research. Data were analysed to present: • the research output; • citation analysis of research articles; • the distribution of South Africa water research articles in peer-reviewed journals; and • the organisations that are providing financial support for South African water research.
Chapter 10	Since 26%* of water research in the SADC region between 1980 and 2016 was produced by researchers affiliated with SADC-ExSA countries, Chapter 9 reported on the analysis of the publication and citation data of these SADC countries where South African citation data were excluded from the data set. Data were analysed to present: • the research output; • citation analysis of research articles; • the distribution of SADC-ExSA water research articles in peer-reviewed journals; and • the organisations that are providing financial support for SADC-ExSA water research.
Part C: CASE STUDY: AN ANALYSIS OF KNOWLEDGE PRODUCTION AND POLICY OR PRACTITIONER ASPECTS OF THE WATER RESEARCH FUND FOR SOUTHERN AFRICA (WARFSA)	
Chapter 11	With a better understanding of knowledge production in the SADC region, and specifically in SADC-ExSA countries, knowledge production from research projects emanating from the WARFSA programme was analysed, making use of scientometric methods
Chapter 12	Having identified research outputs from the WARFSA programme, policy and practitioner aspects were analysed, considering aspects highlighted in the literature review, as presented in Chapter 4.
Chapter 13	Chapter 13 summarises the research findings, conclusions and recommendations.

* Note that some researchers have research affiliations with institutions in South Africa, and also with SADC-ExSA countries, and for this reason, the two datasets do not add up to 100%

From Table 5.4, the systematic analysis of publication and citation data from the SADC countries is evident, where elements such as water research outputs of the countries, authorship trends, citation analysis of water research publications, and insights into the funding support for water research in these countries are discussed. The fact that 81% of all water research during this study period was produced by South African-affiliated researchers, resulted in the data being analysed as three different chapters. In addition, the insights gained through these chapters, provided the basis to undertake an analysis of knowledge produced from WARFSA-funded research projects. In addition, the analysis of water research of the WARFSA programme reported in Chapter 11 provided the basis for reporting in Chapter 12 on an analysis of policy and practitioner aspects evident from the WARFSA-funded research projects.

PART B

SECTOR ANALYSIS AND KNOWLEDGE PRODUCTION IN THE SADC WATER SECTOR

Whereas **Part A** of this study sets out to framing this research project and providing the research methodology, **Part B** now focus on the bibliometric analysis of water research produced in the SADC region. Here, Chapters 6 to 10 first present the institutional landscape in the SADC water sector, as they largely influence the production of water research, followed by the bibliometric analyses of publication data from SADC countries.

Following chapter 10, **Part C**, focus on the knowledge production and policy aspects of WARFSA-funded research and presented in chapters 11 and 12.

Chapter 6

THE LANDSCAPE OF THE SADC WATER SECTOR

The purpose of this chapter is to provide an overview of the landscape of the SADC water sector. To achieve this, the chapter reports on major policies and frameworks in which the sector operates, followed by the presentation of major programmes and university network initiatives in the SADC water sector, which are aimed at developing capacity in the region.

6.1 Introduction

The status and challenges of universities and research institutions in Africa are well documented (see for example Teferra and Altbach 2004). Research institutions in Africa, if compared to the rest of the world, lag behind with under-financed institutions and libraries, overcrowding and the loss of top academics, especially since the 1980s and 1990s (Arvanitis et al., 2000; Mouton, 2008a; Mouton, Effah & Sibuga, 2015; Salmi, 1991). Moreover, within the sub-Saharan countries, research output has seen a decline during the latter part of the previous century, with institutions producing from 1% of world output in 1987 to 0,7% in 1996 compared to global knowledge production (Tijssen, 2007). More recent information however suggests that Africa has increased its world-share of article publications, with African universities and research institutions increasingly producing more articles. This will be presented in more detail later in this study, and specifically section 7.2.1.

Moreover, research institutions operate within a research system that, if effective, contribute to the knowledge production, dissemination and utilisation of research, which, in a globalized world, provide comparative advantages in areas of high growth through the use of technology to address environmental and social challenges (Altbach & Salmi, 2011). Characteristics of such research systems in developed and highly industrialised countries are densely populated formal scientific institutions, such as universities and institutes, conducting Research and Development (R&D) in and outside the higher education sector, and thus contributing towards knowledge production (Mouton, 2008a). In addition, the results of research are typically disseminated through journals which are maintained by scientific publishing houses, and conferences, workshops and seminars are regularly conducted within the science system. Knowledge utilisation and commercialization is also promoted through patent offices, technology incubators and technology transfer offices, thus, if effective, contribute towards an effective research system.

Underfinancing of research and research institutions is probably one of the major contributors for the challenges facing research systems and research output and, in order to finance STI spending, countries aim to budget a percentage of GDP, referred to as GERD.[9] Globally, countries such as Israel and Japan and the Republic of Korea spend 4,48%, 3,46 and 3% respectively on GERD as a share of GDP (UNESCO, 2015). On the African continent, members of the Executive Council of the African Union endorsed the call to member states to increase their Gross Expenditure on R&D (GERD) to at least 1% of GDP to ensure that their programmes and projects be implemented (African Union, 2006). Recent assessments indicate that the global average of public spending on R&D is 0,7% of GDP (OECD, 2015b), and it is thus not surprising that many African countries do struggle to achieve the target of 1% GERD of GDP, as reflected in the *Africa Innovation Outlook-II* report (AIO-II) (NEPAD, 2014:24). Even countries such as South Africa, considered to be spending the highest GERD in Africa, and spending more than three times as much on research as other sub-Saharan countries in 2011, have fallen short of this target (UNESCO, 2011). The latest available figures suggest that South Africa spent 0,77% of GDP on R&D in 2014/2015 (HSRC, 2017a) and 0,80% of GDP in 2015/2016 (HSRC, 2017b). The marginal increase in 2015/2016 was however due to a decline in the GDP growth and better data gathering from universities, rather than in increase in spending on R&D (Van der Merwe, 2017).

In the SADC region, the SADC Regional Indicative Strategic Economic Plan (RISDP) (SADC, 2005) provides a development and implementation framework for SADC regional integration with a planned horizon of 15 years between 2005 and 2025. Within the RISDP, various priority intervention areas are defined, which include cross-sectoral intervention areas such as science and technology (S&T) and also information and communication technologies (ICT). As a co-ordinated effort initiated through the SADC Science, Technology and Innovation Desk in Gaborone (see SADC, 2012b), the Protocol on Science, Technology and Innovation (SADC, 2008) was passed providing SADC member states with the framework for co-operation in matters relating to science and technology. Such plans and protocols probably contributed to the development of STI (Science, technology and innovation) polices in SADC members states, with 11 out of 15 SADC countries having such STI polices in place in 2014 (UNESCO, 2015:539)

It is thus clear that governments across the continent have identified the need to establish frameworks to address the challenges facing higher education in the future. However, organisations such as UNESCO (UNESCO, 2015) state that these STI policies do not always have plans with budgets for the implementation of the policies, which could hamper the execution of these plans in future. Such challenges would also affect research and capacity development of the SADC water sector.

[9] GERD: The total expenditure (current and capital) on R&D carried out by all resident companies, research institutes, university and government laboratories, etc., in a country. It includes R&D funded from abroad, but excludes domestic funds for R&D performed outside the domestic economy (OECD, 2015a).

Having provided an overview of the broader STI landscape in the African and Southern African region, our attention can shift to the SADC water sector.

6.2 African Union and SADC regional water policies and frameworks

In 2002, the African Ministers' Council on Water (AMCOW) was established in Abuja, Nigeria, with the primary objective to "promote cooperation, security, social and economic development and poverty eradication among member states through the effective management of the continent's water resources and provision of water supply services" (AMCOW, 2015:n.p.). With the secretariat office based in Abuja, the AMCOW is a council comprising the African Ministers of Water, meeting annually as a General Assembly at either the African Water Week, or the AfricaSAN meeting, with meetings held to promote the political prioritisation of water, sanitation and hygiene in Africa (see AMCOW, 2015).

Human capacity development in the water sector is a key focal area, which the AMCOW implements through various implementing partners. These partners include the

- African Development Bank (ADB);
- African Water Facility (AWF);
- African Network of River Basin Organisations (ANBO);
- Global Water Partnership (GWP);
- European Union (EU);
- WaterAID;
- UNICEF;
- Sanitation and Water for All (SWA);
- NEPAD African Networks of Water Centres of Excellence;
- African Network on Water (ANEW); and
- African Water Association (AfWA).

Direct funding for the AMCOW secretariat activities is sourced from, grants/donors/support (80%), member contributions (11%) and 9% as other income (AMCOW, 2016).

Within the SADC region, the SADC Water Division has the responsibility to co-ordinate and facilitate water-related activities, which affect SADC member states and operate under the guidance of the Revised Protocol on Shared Watercourses, which was ratified in 1988 and revised in 2000 (Fatch, Manzungu & Mabiza, 2010; SADC, 2010). The offices of the SADC Water Division are located at SADC head office in Gaborone, Botswana.

Research and education have been identified as key focal areas, in developing the skills and knowledge of water professionals required to enhance water resource management (See SADC, 2005; 2011; 2016). This is highlighted by the inclusion of research and education as programmes within the SADC Regional Strategic Action Plan on Integrated Water Resources Development and Management (RSAP-IWRM). Since its inception in 1999, the RSAP has been updated in five-year cycles, with the latest update, RSAP IV, for the period 2016 to 2021 (SADC, 2011; 2016).

In 2015, the SADC Water Division further embarked on a process to establish a SADC water research agenda, with the strategic objective to "Promote evidence-based implementation of SADC water programmes and projects through multi- and inter-disciplinary research, and synthesis of existing and new information, which will lead to a realisation of SADC developmental goals" (SADC, 2015:v)

While the SADC water research agenda acknowledges that many research efforts are undertaken in the region, a need has been identified at the SADC Water Division to consolidate, streamline and institutionalise the research, to ensure that research stays relevant to the needs of the region (SADC, 2015:1).

Divided into two focal areas, namely infrastructure for health, livelihoods and economic development, and water resource management and environment, the SADC water research agenda further sets out specific topics under each theme, as presented in Table 6.1.

Table 6.1: SADC water research agenda research focal areas and themes

FOCAL AREA/THEME	TOPIC
Focus area 1: Infrastructure for health, livelihoods and economic development	
Theme 1: Development and sustainable implementation of resilient water-related infrastructure	1. Water supply and sanitation in rural areas
	2. Water supply and sanitation in urban areas
	3. Water supply and sanitation in peri-urban areas/slums
	4. Agricultural water management for food security and poverty alleviation
Theme 2: Innovation in affordable and appropriate technologies and innovative approaches and practices	1. Waste water treatment technologies in urban, peri-urban and rural settlements and industrial areas
	2. Support to self-supply technologies for domestic uses and agriculture water management
Theme 3: Sustainable water institutions	1. Responsive local public, and public private partnership (PPP) water institutions
	2. Decision-support tools to enable effective planning and management of water resources
	3. Accountability, transparency, integrity for maximum societal benefits
	4. Implementation and monitoring methods of water and sanitation services
Theme 4 : The human right to water	1. Social, economic and environmental viability of large-scale investments in agriculture

FOCAL AREA/THEME	TOPIC
	2. Support to local investments incorporating gender, and legal and social protection of small-scale water users
	3. Implications of human right to water supply, sanitation and hygiene
	4. Core minimum service levels for multiple uses including the right to food
Focus area 2: Water resource management and environment	
Theme 1: Assessment of surface and groundwater resources	1. Water quantity and quality assessment
	2. Regional water quality guidelines for rivers, lakes and aquifers
	3. Data processing, storage standards and dissemination
	4. Suitability of water productivity performance indicators
	5. Optimisation of monitoring networks
Theme 2: Operational rules for water resource management	1. System operating rules for environmental flows, irrigation management and flood response
	2. Impact of hydropower reservoir discharges on downstream productive uses and the environment
Theme 3: Impact of urbanisation on water resources	1. Urban hydrology across various human settlements and economic zones
	2. Sustainable urban design
Theme 4: Water governance and institutional arrangements	1. Institutional models for effective water governance
Theme 5: Water and land	1. Assessment of irrigation resources
	2. Sustainable land management, including the land-water nexus

Source: SADC (2015)

The SADC water research agenda proposes certain implementation arrangements, with WARFSA as the institutional home of the agenda. As a co-ordination mechanism, it was proposed that WARFSA should obtain financial resources to fund water research, either in the form of innovation funds, competitive grants, commissioned research or a flexible grant. It is further acknowledged in the SADC water research agenda that water research would occur in the SADC region, which is not funded through the WARFSA, but which is either affiliated with WARFSA or non-WARFSA-affiliated.

The SADC water research agenda was approved in 2015 by the SADC Ministers of Water, and further steps were taken by the implementing agencies of the SADC Water Division. The implementing agents being the NEPAD Southern African Network of Water Centres of Excellence (NEPAD SANWATCE) as implementing agent of WARFSA, and WaterNet, a capacity development subsidiary programme under the SADC Water Division. Both these institutions are discussed in more detail in later in this document (sections 6.3.1 and 6.3.2).

6.3 Programmes and network initiatives

Since the early to mid-1990s, various African and in terms of this study, Southern African, initiatives have been undertaken to address the water, sanitation and hygiene (WASH) needs of all stakeholders through education, training and scientific research. Such initiatives often involve public and private institutions of higher education, such as universities and research institutions. It has been established that at least 28 accredited public universities offer water courses in the SADC region, with at least one accredited public university per SADC country, which offers high-level research and capacity development in the water sector (Mannel et al., 2012; Matete, 2010). Many of these universities and research institutions are involved in formal and informal collaborations. Such collaborations are often between individual researchers, or as institutions through formal programmes, often mandated either from a continental level, such as the African Union (AU) and the New Partnership for African Development (NEPAD), or from a regional level, through the SADC or directly from a country level. In order to provide some overview, various institutions, collaboration programmes and initiatives are discussed. For the purpose of this study, the institutions and programmes were selected as they were either implementing agents of SADC through the SADC Water Desk (see SADC, 2012a) in Gaborone, or they are national and regional programmes often reporting to SADC ministries of water and SADC ministries of science and technology, which provide them with some level of prominence.

6.3.1 WaterNet

Established in 2000, WaterNet has grown to be a major capacity development programme in the SADC water sector. In addition, the SADC heads of state agreed to approve WaterNet status as a subsidiary programme under the SADC Water Division and implementing agent of the SADC Water Division in 2012. The vision of the WaterNet programme is ‘a future in which SADC has the institutional and human capacity to educate and train its own water managers’. Today, WaterNet is a regional network of 70 Southern African-based university departments, research and training institutes, specialising in water. The network builds regional institutional and human capacity in Integrated Water Resource Management (IWRM) through training, education, research and outreach by harnessing the complementary strengths of member institutions, in the region and elsewhere (WaterNet, 2016b).

Its core activity is a master’s degree programme in IWRM, with the establishment of the programme well documented (Van der Zaag, 2005; Wright, Savenije & Van der Zaag, 2001). As a SADC regional programme, the master’s degree programme in IWRM has trained 427 graduates from the SADC region between 2000 and 2015, if whom 34% are women (Kileshye-

Onema, 2014; WaterNet, 2016c). Further specialisation modules are offered to students at either of these universities:

- University of Dar-es-Salaam (Hydrology);
- University of Zimbabwe (Water Resources Management);
- University of Botswana (Water and Land); and
- the University of KwaZulu-Natal (Geographical Information Systems [GIS] and Earth Observation).

Further specialisation modules are offered at the following universities:

- University of Malawi (Water and Environment);
- Namibia University of Science and Technology (Water Supply and Sanitation); and
- University of the Western Cape (Water and Society), from where students complete group work and also a dissertation in order to qualify for a master's degree in IWRM.

Furthermore, professional training programmes develop competency through short courses (in collaboration with SADC Water Division, Cap-Net, and the Global Water Partnership Southern Africa [GWP SA]). Additionally, WaterNet co-convenes the annual WaterNet/WARFSA/GWP SA symposium, in collaboration with WARFSA and GWP SA. This has become the key annual event in water research in East and Southern Africa since 2000 (WaterNet, 2016a). At recent symposia, an average of approximately 400 delegates have attended, which presents a major capacity development opportunity in the SADC region. As an output of these symposia, annual peer-reviewed special editions of the *Physics and Chemistry of the Earth (PCE)* journal is published. These special issues of PCE have been published since 2002, with more than 375 articles published over the years.

6.3.2 NEPAD Southern African Network of Water Centres of Excellence (NEPAD SANWATCE)

There are various initiatives on the African continent to establish centres of excellence amongst African higher education organisations, such as the World Bank's African Centres of Excellence project (Tijssen & Kraemer-Mbula, 2017). Started in 2013, and with an project budget of US$ 290,80 million, the first phase of the project had as its objective to identify 19 centres of excellence in Western and Central Africa (World Bank, 2014).

As far back as 2003, the African Ministerial Council on Science and Technology (AMCOST) adopted Water Science and Technology as one of the flagship programmes of NEPAD (NEPAD SANWATCE, 2013). This culminated in the issuing of a joint declaration between AMCOST and AMCOW to establish networks of water centres of excellence across the African continent (NEPAD SANWATCE, 2013). With the establishment of these networks of water centres of excellence (WCoEs), NEPAD also acted as facilitating agent (see NEPAD

SANWATCE, 2013). In 2009, the heads of state also approved the integration of NEPAD into the African Union (AU), which was aimed at improving NEPAD's efficiency (Ndhlovu, 2009).

With a focus to facilitate high-level scientific research amongst networks of higher education and also research institutions, the objective of the WCoEs is to assist governments by providing policy instruments such as policy briefs, best practices and guidelines within the WASH sectors. To date, a Southern African Network of Water Centres of Excellence (SANWATCE) has been established within SADC with Stellenbosch University as coordinating hub, with ten universities and research institutions in Botswana, Malawi, Mozambique, South Africa, Zambia, Namibia and Zimbabwe being members of the network. It is the objective to expand to include at least one institution in each of the 15 SADC countries, in order for the network to be a truly SADC representative network (NEPAD SANWATCE, 2013).

Moreover, a Western African Network of Water Centres of Excellence (WANWATCE) has been established within the Economic Community of West African States (ECOWAS), with the University of Cheikh Anta Diop (Senegal) as coordinating hub with five universities and research institutions in Senegal, Burkina Faso, Nigeria and Ghana being members of the network in West Africa (NEPAD SANWATCE, 2013).

There are plans to expand the networks in other regions (Central, East and North Africa) in the coming years, with most recent developments in 2017 underway to establish a Central and East African Network of Water Centres of Excellence (CEANWATCE).

During the 24th SADC Water Resources Technical Meeting (which was ratified by the SADC ministers of Water) held in Lusaka in 2013, it was agreed that, amongst other matters, the NEPAD SANWATCE would:

1) collaborate with WaterNet and have joint programme developments;
2) focus on research and technology transfer whereas WaterNet would focus on capacity building and training; and
3) be the implementing agency for the WARFSA project due to their comparative advantage in terms of mandate and expertise (NEPAD SANWATCE, 2013).

Of further relevance to the institutionalisation of the NEPAD SANWATCE, the SADC ministers responsible for science, technology and innovation, education and training, noted and supported the activities of the NEPAD SANWATCE during meetings in Maputo (2014) and Botswana (2016), and further called upon member states to nominate institutions to be members of the regional research capacity development network (NEPAD SANWATCE, 2016).

6.3.3 Applied Centre for Climate & Earth Systems Sciences (ACCESS)

ACCESS was initially launched as a community network in 2007 with the aim to increase the understanding of climate change in Africa and to further global earth systems science, which subsequently evolved into a South African NRF Centre of Excellence in 2009 and hosted by the CSIR (CSIR, 2009; Sweijd, Palmer, Sikutshwa & Mulaudzi, 2015). Within the ACCESS, various research groups, research councils, universities and agencies participate in the programme with the combined objective to deliver a range of research outputs, which are aligned the with the Department of Science and Technology's (DST) Global Change Grand Challenge (GCGC). Moreover, as a co-operation platform, the ACCESS programme provides research and education outputs across a range of disciplines within the Southern African earth system (SAES).

ACCESS activities are arranged in order to

- deliver research aligned with seven themes (see below);
- education and training of post-graduates;
- workshops and networking through conferences and meetings;
- knowledge brokering; and
- service rendering (Sweijd et al., 2015).

Research themes are:

- Theme 1 Weather and Climate Variability: Fundamentals, Predictability and Application;
- Theme 2 Climate Change and Impacts;
- Theme 3 Water;
- Theme 4 Environmental change, ecosystem services and livelihoods;
- Theme 5 Land use and land cover change in rural and urban environments;
- Theme 6 Marine;
- Theme 7 Biogeochemistry and Earth System Modelling (Sweijd et al., 2015).

In order to provide some indication of annual research outputs directly resulting from ACCESS, Table 6.2 is presented. In total, 78 research outputs have been produced (with one article being prepared in theme 7) in the 2014/2015 financial year, across the various research themes, and further resulting in 28 graduations (Sweijd et al. 2015:3). The various research comprise 53 articles (either published, submitted, in press or in preparation) and 25 conference proceedings. In addition, 28 indirect research outputs in the form of Honours, MSc and PhD degrees which was funded by Germany and implemented through ACCESS as the agency, have resulted in the 2014/2015 financial year (Sweijd et al. 2015:3536).

Table 6.2: Research outputs of the ACCESS (2014/2015 financial year)

	Theme 1	Theme 2	Theme 3	Theme 4	Theme 5	Theme 6	Theme 7	Total
Published	11	6		10	7	2	1	37
Submitted/in press		1	2	4	6	1	1	15
In preparation							1	1
Conferences	3	2	10		5	2	3	25
Total	14	9	12	14	18	5	6	78

Source: Sweijd et al. (2015)

Moreover, with the main thrust of ACCESS being on the support of post-graduate students, 76 post-graduate students were supported, ranging from National Diplomas (2) to Honours degrees (3), MSc degrees (31), PhD degrees (38) and post-doctorates (2) (Sweijd et al. 2015:41).

As a South African National Research Foundation Centre of Excellence, funding is primarily provided by the South African Department of Science and Technology through the NRF.

6.3.4 Southern African Science Service Centre for Climate Change and Adaptive Land Management (SASSCAL)

The SASSCAL programme is a joint programme between Angola, Botswana, Namibia, South Africa, Zambia and Germany. It was established in 2010 and involves researchers from various research institutions in the countries mentioned. As part of the governance of the programme, the secretariat is located in Windhoek, Namibia (SASSCAL, 2016).

The SASSCAL programme focusses on providing information and services relating to a better understanding and assessment of the impact climate change and further land management changes within five thematic areas, namely climate, forestry, agriculture, water and biodiversity. Through initial funding from the Federal Ministry of Education and Research (BMBF) of Germany, 88 research projects were launched in the various partner countries, addressing issues relating to the five thematic areas, with 17 tasks specifically relating to the water theme, in order to develop hydrological and hydrogeological baseline data in the Southern African region (Helmschrot & Jürgens, 2015; Jörg Helmschrot et al., 2015). The South African Department of Science and Technology has further provided financial support to South African researchers at the Universities of Stellenbosch, the Western Cape, KwaZulu-Natal and the CSIR, for research activities relating to the water theme in South Africa, through the NRF.

Apart from the research projects initiated through the SASSCAL programme, the programme has established the SASSCAL WeatherNET in 2013/2014 (see Helmschrot et al., 2015), which provides additional infrastructure to the number of automatic weather stations (AWS) in

Southern Africa, supporting efforts in improving the national weather monitoring systems (Helmschrot et al., 2015; Kaspar et al., 2015).

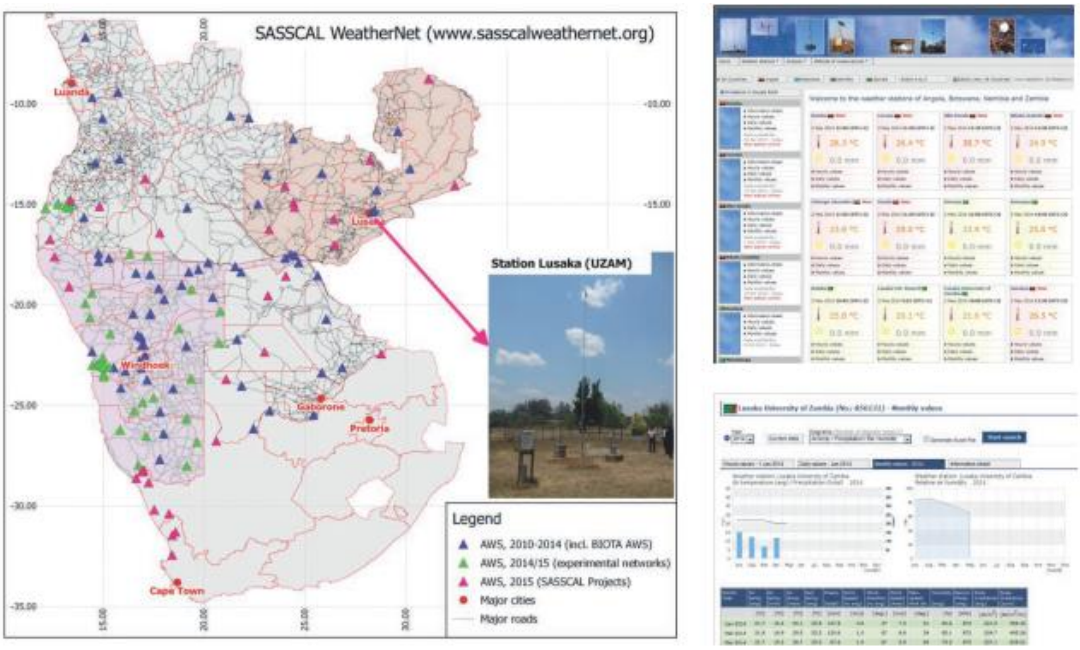


Figure 6.1: SASSCAL WeatherNet coverage and website

Source: Helmschrot et al. (2015)

In 2015, this network of AWS comprised 87 stations across the Southern African region, with plans to extend it with an additional 60 stations in 2016 (Figure 6.1). Recent indications are that the network comprise of 156 weather stations in Angola, Botswana, Namibia, Zambia and South Africa (SASSCAL, 2018), with near real-time data of major climatological variables being transmitted from the weather stations to the SASSCAL WeatherNet website (www.sasscalweathernet.org).

6.4. International organisations

Various international organisations have offices in the SADC region, from where programme activities are undertaken to support the SADC water sector.

6.4.1. Global Water Partnership (GWP)

The Global Water Partnership (GWP) was established in 1996 with the objective to foster Integrated Water Resources Management (IWRM), after the UNDP (United Nation Development Programme) and World Bank had issued an invitation to contribute to the development of a GWP. Global water security is at the heart of the GWP vision, which is executed through the support of initiatives which, in a sustainable manner, develop and manage water resources at all levels and foster IWRM. GWP further aims to influence water governance at all levels, through three strategic goals, which GWP outlines in the GWP Strategy 2014-2019 (GWP, 2014), namely:

- Goal 1: Catalyse change in policies and practice.
- Goal 2: Generate and communicate knowledge.
- Goal 3: Strengthen partnerships.

As a global organisation, GWP is organised in 13 regions across the globe, partnering extensively with organisations who support the principles of IWRM in countries from the regions. In 2015, GWP reported no fewer than 3 200 partnerships in 182 countries. Global partners are predominantly Networks/non-governmental organisations (NGOs) (38%), followed by governments (25%), research/education institutions (16%), private sector (13%), professional associations (4%), and international organisations and other partners comprising 2% each (GWP, 2015b).

In the Southern African region, the regional office of GWP SA is based in Pretoria, South Africa, with a strong relationship with SADC Water Division (having an 'implementing partner' status with SADC), countries in the Southern African region and river basin organisations (RBOs).

One of the major contributions of GWP SA in recent years, has been the major role it played in mobilising partner dialogues in establishing the SADC Water Regional Strategic Action Plan (RSAP), which provides a framework and strategy for the sustainable, integrated and co-ordinated development of water resources in the SADC region, with the fourth version (RSAP IV vision 20162020), being approved by the SADC ministers for water in September 2015 (SADC, 2016).

Core funding for the GWP is primarily provided through globally raised income from donor countries such as Austria, China, Denmark, the European Commission, Germany and the Netherlands. About a third of funding raised in 2015 came from locally raised funds and funding for specific activities (GWP 2015a:32). GWP further assists governments in securing funds with funding agencies, as in the case where GWP SA supported the government of Mozambique in securing funds from the African Water Facility (AWF), a multilateral fund administered by the African Development Bank (GWP 2015a:18). GWP SA further supported the Orange-Senqu River Commission (ORASECOM), in mobilising funds, again from the AWF, for the development of a climate change adaptation plan in line with the SADC Climate Change Adaptation Strategy (GWP, 2015b:17).

In terms of generating and communicating knowledge (Goal 2), GWP has developed various knowledge products through its GWP Technical Committee, providing high-quality advice for practitioners (GWP, 2015b). Various technical articles have been produced over the years in collaboration with partners, many of whom are from the university partners in the networks. In the 2015 annual report (GWP 2015b:3435), GWP reported the publication of 23 background articles, 15 policy briefs, five technical briefs, seven prospective articles and nine technical focus articles over the years. Most recently, the GWP Technical Committee published the *Forecasts of mortality and economic losses from poor water and sanitation in sub-Saharan Africa* (GWP, 2015a).

6.4.2. United Nations Educational, Scientific and Cultural Organization (UNESCO)

With a newly established Southern African regional office of UNESCO, located in Harare, Zimbabwe, the UNESCO office serves as focal point for co-operation with SADC, as well as for the Common Market for Eastern and Southern Africa (COMESA) (UNESCO, 2014a).

The UNESCO Framework Programme for Research, Education and Training in Water (FETWater) was launched in 2002 (UNESCO, 2006). It supports IWRM training and capacity building networks in South Africa. FETWater develops training materials, capacity audits and short courses. In 2014, Phase III of the FETWater programme commenced, with a distinct regional focus within the SADC. Currently, the programme is being implemented by the South African Department of Water and Sanitation with the WRC as implementing agent (WRC, 2015a).

Furthermore, UNESCO encourages the UNESCO structure including the Category I & II Centres of Excellence and Chairs to carry out a joint International Hydrological Programme (IHP), in collaboration with national commissions and the governments of its 190 member states (UNESCO, 2017a). Related to the Southern African region, a UNESCO Category II Centre has been established in 2013/2014 at the African Centre for Global Change and Water Resources Research (ACGCWRR) at the University of KwaZulu-Natal (UKZN) (UKZN, 2014).

UNESCO has also established a number of research chairs in the Southern African region, as reflected in Table 6.3. Through these institutions, UNESCO carries out research, education and capacity building activities in the fields of medicine, governance, communication, education, energy, water, environment and infrastructure.

Table 6.3 : UNESCO research chairs in the SADC region as at 30 June 2018

Description	Year	Country
1. UNESCO Chair in Higher Education	1994	Mauritius
2. UNESCO «Oliver Tambo» Chair of Human Rights	1996	South Africa
3. UNESCO Chair in Geohydrology	1999	South Africa
4. UNESCO Chair in Biotechnology	1999	South Africa
5. Chaire UNESCO pour la Culture de la Paix, le Règlement des Conflits, les Droits Humains, la Démocratie et la Bonne Gouvernance	2000	Democratic Republic of the Congo
6. UNESCO Chair in Open and Distance Learning	2001	Botswana
7. UNESCO Chair in Renewable Energy and Environment	2001	Zambia

8. UNESCO Chair in Values Education-Learning to Live Together	2005	South Africa
9. UNESCO Chair in Educational Policy, Planning, Management and Research Development	2006	Uganda
10. UNESCO Chair in teacher education for diversity and development	2009	South Africa
11. UNESCO Chair in marine technology	2009	United Republic of Tanzania
12. UNESCO Chair in Education Law	2010	South Africa
13. UNESCO Chair in Nanosciences and Nanotechnology	2015	South Africa
14. UNESCO Chair on Lifelong Learning, Youth and Work	2016	Uganda
15. UNESCO Chair in Science, Technology and Innovation (STI) and Leadership	2016	United Republic of Tanzania
16. UNESCO Chair on Sustainable Water Research for Climate Adaptation in Arid Environments	2017	Namibia
17. UNESCO Chair on Community Media	2017	South Africa
18. UNESCO Chair on African Food Systems	2017	South Africa

Source: UNESCO (2018)

The World Water Assessment Programme (WWAP) is a joint initiative of the 26 UN bodies that constitute UN Water to compile the World Water Development Report (WWDR) and monitor freshwater issues in order to provide recommendations, develop case studies, enhance assessment capacity at a national level and inform the decision-making processes (UNESCO, 2017b).

6.4.3. International Water Management Institute

The International Water Management Institute (IWMI) is one of 15 international non-profit research centres that focus on food security on behalf of poor people in developing countries under the umbrella of the Consultative Group on International Agricultural Research (CGIAR). IMWI itself employs about 350 people in 10 countries and specifically aims at improving the management of land and water resources for food, livelihoods and the environment. Research is the core activity and is organised around four priority themes: water availability and access, productive water use, water quality, health and environment, and water and society.

6.4.4. Stockholm International Water Institute

In March 2014, the Stockholm International Water Institute (SIWI) opened a regional office in Pretoria, South Africa with the aim to develop SIWI's African programmes further. The office has identified opportunities to promote bi-directional experience sharing with African organisations, identify the relevance of SIWI's work on the continent, and promote engagement with African organisations at the annual World Water Week, which takes places in Stockholm, Sweden, and organised by SIWI (SIWI, 2014).

6.5. Research and innovation units

Apart from public and private universities, various public and private research institutions are found in the Southern African region (as presented in Annexure A), with many institutions conducting water research. These research councils and centres are often closely linked to government ministries, as in the case of Lesotho, Malawi, Mozambique and Tanzania and to a lesser, but still significant extent, South Africa. Smaller countries invariably do not have significant research capacity or infrastructure, and often enter collaborations with other research institutions in the region or internationally on specific topics, such as the case of Swaziland, Lesotho and the Seychelles (Pouris & Ho, 2013). It is clear from the type of research institutions in the Seychelles (Annexure A) that marine research is of high importance to the country. Agricultural and health-related research is also clearly of high importance, given that research institutions related to these fields of are prevalent in most countries, often associated with governments.

In South Africa, research institutions are well resourced through funding councils such as the National Research Foundation (NRF), Technology Innovation Agency (TIA), the Medical Research Council (MRC), and the Water Research Commission (WRC).

6.5.1. The South African Water Research Commission (WRC)

As a dedicated and substantial funder of water research in South Africa, an overview of the activities and funding of the WRC is provided.

The WRC promotes the co-ordination, co-operation and communication in the area of water research and development by establishing water research needs and priorities, and along with the South African NRF, the WRC is a substantial research funder in the Southern African water sector. This is in line with findings by Pouris (2013:35) when he assessed the state of water research in the South African water sector, which was discussed in detail in chapter 3 (section 3.2.2).

With primary funding from the South African Department of Water Affairs and Sanitation[10] (DWS), the WRC stimulates funding of water research according to identified priority areas, predominantly in South Africa[11] (See WRC, 2017). Additionally, the WRC promotes effective transfer of information and technology. At the WRC, research is conducted within four key strategic areas (KSAs), each with specific thrust focus areas. The KSAs are

- KSA 1: Water Resource Management;

[10] Note that the current Department of Water and Sanitation has changed names over the past few years. In 2009, the Department of Water Affairs and Forestry was renamed the Department of Water and Environmental Affairs, which was renamed the Department of Water and Sanitation in 2014.
[11] There are however plans to expand this geographical context to include the broader Southern African region, but that would require an amendment to the Water Research Act (Act No. 34 of 1971)

- KSA 2: Water-Linked Ecosystems;
- KSA 3: Water Use and Waste Management; and
- KSA 4: Water Utilisation in Agriculture.

Since its establishment in 1971, the WRC has contributed significantly to water-related research and capacity development. A glimpse of its contribution is reflected in Table 6.4, indicating support for 584 new research projects for the seven financial years between 2009/2010 to 2015/2016, with significant increases in the 2010/2011 and 2014/2015 financial years. Initial indications are that, for the 2016/2017 financial year, the number of new projects has again been over 100 (WRC, 2017). It has been stated by the WRC that it receives approximately three time more applications than it is able to fund with existing resources (WRC, 2013; 2014), further providing an indication of the demand for research funding in the sector. Over the same period, 573 projects have been completed relatively in line with new projects undertaken, indicating good management of projects, and 3 062 students were supported (of whom 64% were from previously disadvantaged backgrounds). Note that in the 2015/2016 financial year, the WRC did not report on the students supported, but indicated that they had supported 50 project leaders from disadvantaged backgrounds. Since 2001, when the WRC started to record student numbers systematically, 6 952 students have been supported through WRC-funded research projects, while between 2000 and 2011, 250 PhDs and 1 331 master's degrees were awarded (Jacobs, Du Plessis et al., 2014). It is worth noting that the percentage of students supported from previously disadvantaged backgrounds increased from 62% in 2009/2010 to 83% in 2014/2015 (Table 6.4).

Table 6.4: WRC project and student numbers in relation to spending

	2009/2010	2010/2011	2011/2012	2012/2013	2013/2014	2014/2015	2015/2016	TOTAL
Applications received (according to 2013/14 and 2012/13 annual reports, average oversubscribed by 3:1)	**	**	**	**	268	**	**	**Not able to calculate[12]**
New projects (increase from previous year)	62	77 (24,19%)	74 (-3,9%)	81 (9,46%)	87 (7,41%)	113 (29,86%)	90 (-20,35%)	**584**
Completed projects	57	76	96	85	87	77	95	**573**
Number of students supported	562	520	506	494	484	496	***	**Between 2009 and 2015: 3 062**
Previously disadvantaged individuals (PDI) students supported %	346 (62% of students)	311 (60% of students)	268 (53% of students)	267 (54% of students)	339 (70% of students)	412 (83% of students)	50 project leaders	**1 943 or 64%**
Total revenue (ZAR'000)	153 997	154 173	176 246	184 535	203 816*	261 205	273 320	**1 407 292**
Expenditure on research projects excl. dissemination ZAR'000. (% change from previous year)	86 700	83 800 (-3,34%)	110 485 (31,84%)	116 726 (5,65%)	118 521 (1,54%)	176 453 (48,88%)	184 104 (4,34%)	**876 789**

* Restated in 2015
** Not published in annual report
*** In 2015/2016, the WRC did not report on the number of PDI students, but did indicate the number of PDI project leaders.

Source: WRC annual reports (WRC, 2010; 2011; 2012; 2013; 2014; 2015b; 2016)

[12] The total could not be calculated, since the annual number of applications were not reported in the WRC annual reports

Income for the WRC is predominantly generated through levies from bulk water users in South Africa, which is channelled from the South African Department of Water and Sanitation, Rand Water Board, and the Umgeni Water Board. To a lesser extent, funds are also generated from other sources, which include the leveraging of funds (by 2013, leveraged income amounted to 10% of total income) (Jacobs, Du Plessis et al., 2014), where the total revenue for the six financial years (20092015) amounted to no less than ZAR1,1 billion. Funding is used for operational and research dissemination expenses, with the bulk allocated towards the funding of research at universities, science councils and non-government research institutions. In the seven financial years between 1999/2010 and 2015/2016, expenditure in research (excluding research dissemination) amounted to ZAR 876,789 million an average of 62% of the total budget, with substantial increases in research spending in 2011/2012 and 2014/2015 as reflected in Table 6.4. To put WRC expenditure on water-related research in context, Pouris (2015) indicated that in 2014, the WRC funded 65% of water-related research in South Africa, the CSIR 16%, Mintek 9% and the NRF 8%. This is based on national water-related spend of R240 million in 2014, which has also increased significantly from R50 million in 2000 (Pouris, 2015:05).

The WRC further contributes towards knowledge in the sector, through publications such as the *WaterWheel*, which is widely read by schoolteachers, farmers, environmental groups and policymakers, and the scientific journal *WaterSA*, which is aimed at the scientific community (Table 6.5). The WRC further supports technical and policy notes, ministerial briefs, manuals, guidelines and events. Since 2013, there has been marked increases in technical and policy briefing notes and ministerial briefs, indicating the important role the WRC plays in policy formulation. The WRC is also involved in a number of knowledge-sharing events through dialogues. Information is readily available through the WRC knowledge hub, which is accessible on their website (http://www.wrc.org.za/).

Table 6.5: WRC knowledge sharing

	2009/2010	**2010/2011**	**2011/2012**	**2012/2013**	**2013/2014**	**2014/2015**	**2015/2016**
Number of technical and policy briefing notes	31	30	36	38	80	**	12
Number of ministerial briefs	**	1	4	2	12	8	12
Number of innovations and products	3 patent applications submitted	2 patent applications submitted	**	18	24	22	31

Manuals, guidelines etc. produced	Specific count not available	Specific count not available	**	**	25	18	26
Knowledge-sharing events through dialogues	20 knowledge-sharing events	20 Technical workshops and 11 other events	21	37	46	31	16

** Not published in annual report

Source: WRC annual reports (WRC, 2010; 2011; 2012; 2013; 2014; 2015b; 2016)

As indicated earlier in this section, the WRC makes a significant contribution in building student capacity through the research projects. Although the WRC primarily funds research undertaken at South African institutions and organisations, students from the SADC region are invariably involved in projects (Table 6.6), where, for example, 11% and 18% of students came from the SADC region in 2011/2012 and 2012/2013 respectively. Students further afield from Africa and also internationally are supported when they study at South African institutions, although these numbers are very low. Although not significant, such support contributes towards the general research capacity within the SADC region and the African continent.

Table 6.6: Country of origin of students who participated in WRC-funded projects

	2009/2010	2010/2011	2011/2012	2012/2013	2013/2014	2014/2015	2015/2016
Total number of students	562	520	506	494	484	496	**
SA	**	**	384 (76%)	349 (65%)	**	**	**
SADC (excl. SA)	**	**	56 (11%)	91 (18%)	**	**	**
Africa (excl. SADC)	**	**	** specific number not published	30 (0,6%)	**	**	**
Global	**	**	** specific number not published	21 (0,4%)	**	**	**
Unspecified	**	**	** specific number not published	3 (0,006%)	**	**	**

** Not published in annual report

Source: WRC annual reports (WRC, 2010; 2011; 2012; 2013; 2014; 2015b; 2016)

6.6. Societies, associations and academies

The Water Institute of Southern Africa (WISA) is the only professional organisation that represents the whole water sector in Southern Africa. Its purpose is building expertise and sharing knowledge between members to improve the quality of life. Its main capacity-building and knowledge-sharing arm is eWISA, which relays information through its website (WISA, 2014). In addition, WISA organises a biennial conference and exhibition, at various locations in South Africa, which brings water professionals together from all over the country (WISA, 2017).

In partnership with WISA, the South African Young Water professionals (YWP ZA) provide a platform for young people to be connected through a network. This organisation falls under the auspices of the International Water Association (IWA). The programme is implemented through the South African provinces, with regular meetings organised through provincial steering committees. In recent years, the YWP ZA have been organising an annual conference, with participants partaking in the 2015, 2016 and 2017 events (YWP ZA, 2017).

6.7. Other networks

Other networks include Cap-Net, which comprises a partnership of autonomous international, regional and national institutions and networks committed to capacity building in the water sector, especially IWRM and the achievement of the Sustainable Development Goals (SDGs). Since 2018, Cap-Net has a virtual campus in Pretoria, South Africa, and coordinated from a secretariat in Buenos Aires, Argentina (Cap-Net, 2018).

6.8. Summary and conclusion

The objective of this chapter was to provide an overview of research and capacity development in the Southern African water sector, with various international organisations supporting local universities, institutions and network initiatives active in the region. Research has indicated that at least one university or research institution exists in each SADC country, which provides some sort of research and capacity development programme. These institutions operate with challenges, which include understaffing and institutions with very little infrastructure, highlighting the need for research collaboration within Africa and further between Africa and the political North, and emerging South-South collaborations, in order to share knowledge, skills and techniques and for researchers to overcome intellectual isolation.

Strategic water policies and frameworks have been developed not only by the African Union, but further within the SADC region. Few implementation and budget plans however exit, which could affect future Science, Technology and Innovation (STI) benefits in the region. However, with many African (including SADC) countries struggling to spend the AU target of at least 1% of GDP on R&D, it is imperative that SADC members states implement their STI policies, for if implemented successfully, STI could stimulate the region to achieve its development goals, in collaboration with the various universities and research institutions.

As initial steps, regional research collaboration could contribute towards the research and capacity in the SADC water sector, and for this reason, it is not surprising that various collaborative networks have been established. Some of these networks are mandated at an African continental level, such as the NEPAD Southern African Network of Water Centres of Excellence (NEPAD SANWATCE), and others SADC regional such as the WaterNet network. Other research programmes and international organisations are ACCESS, SASSCAL, GWP with its SADC regional office GWP SA, UNESCO, the IWMI and SIWI with a regional office in South Africa, and Cap-Net. In addition, the South African WRC, WISA and YWP ZA increasingly find a foothold in the SADC region.

The question can now be asked to what extent research has contributed towards knowledge production in the SADC water sector over the past few years, given the various policies, strategies and organisations initiating research programmes through local universities and research institutions.

In the next chapter, water research knowledge production, through research institutions in the SADC region, will be discussed in order to determine who the major knowledge producers in the region are. We also present the results of our citation analysis of the articles produced by researchers who provide financial support for research in the region.

Chapter 7
KNOWLEDGE PRODUCTION IN THE SADC WATER SECTOR

7.1 Introduction

Whereas the previous chapter focussed on the institutional landscape of the SADC water sector, our focus now shifts to the production of scientific knowledge. We define scientific knowledge here as referring to the production of peer-reviewed articles, conference proceedings, books and book chapters as well as master's and PhD dissertations. As far as articles are concerned, we report on articles captured in the Clarivate Analytics Web of Science (WoS) and Elsevier's Scopus database. These citation databases make data available for bibliometric research and provide answers into the nature of scholarly activity, such as how data are structured, how the research develops and the actors in the research perform (Moed, Glänzel & Schmoch, 2005).

The purpose of this chapter is to provide the context for knowledge production in the SADC water sector. Context does not only relate to when the Water Research Fund for Southern Africa (WARFSA) was initiated in 1999 and concluded in 2007, but includes the years preceding 1999 until 2016. With Chapters 8, 9 and 10 providing the results of an in-depth bibliometric analysis of knowledge production in the SADC water sector, the aim of this chapter is to provide context of knowledge production in the SADC water sector as it relates to the African continent as a whole and globally. Here, primary data are presented indicating the share of water research as a percentage of research undertaken in various SADC countries between 1980 and 2016 and how it relates to Africa as a whole and globally. In order to assess changes in growth rate, data over two periods are presented, i.e. 1980 to 1999 and 2000 to 2016. In addition, the results of an activity index (AI) calculation are presented. An AI provides an indication of the relative effort a country devotes to a research field (Frame, 1977; Schubert & Braun, 1986).

7.2 SADC water research in an African and global context

This section present an overview of water research in the SADC region, within an African and global context. In addition, the time span chosen was 1980 to 2016, which would indicate changes in annual publication and citation trends over a period of time. The dates are not unimportant, given the political backdrop of the SADC region since the early 1980s, and an ever-increasing awareness developing with a focus on research and capacity development in the region (this is presented in more detail in the research methodology chapter, and specifically in section 5.3.1).

7.2.1 Water research in SADC countries

In Table 7.1, the share of water research at a global, African continental, SADC regional and individual SADC country level for the period between 1980 and 2016 is presented. Such a long period could however mask smaller trends, and for this reason, data are further presented in two periods, namely 1980–1999 and 2000–2016. Given the few water research publications in the early 1980s (see Table 7.1), the two-year difference (i.e. 1980–1999 and 2000–2016) in the time periods did not affect the calculations in the table materially. The year 2000 is further significant, as it coincided with the first versions of the RSAPs, WaterNet, WARFSA and the first annual WaterNet/WARFSA/GWP-SA symposium, which had evolved to become the key annual event in water research in East and Southern Africa since 2000 (see WaterNet, 2016a; Wright et al., 2001). At recent symposia, on average, approximately 400 delegates have attended (see WaterNet, 2016a), which presents a major capacity development platform in the SADC water sector.

Globally, water research comprises between 0,51% and 0,63% of total research, whereas on the African continent, water research comprises between 1,39% and 1,66%, reflecting slight increases between the two periods before and after 2000 (Table 7.1). Within the SADC region, the picture changes slightly, with water research comprising a constant share of 1,80% between the two periods, when considering all SADC countries as a whole. What is however significant, is the dominance of water research emanating from South Africa over the years. Water research from South Africa comprised 90,07% of all water research in the SADC region before 2000 and declining to 77,46% after 2000. When one excludes South African publications from the total SADC water research scenario (referred to as SADC-ExSA countries), the significant increase in the share of SADC-ExSA countries is evident as the share of water research publications increased from 10,26% in the period 1980–1999 to 26,32% in period 2000–2016 (Table 7.1). As is evident from Table 7.1, the most significant increases came from –

- Tanzania (from 1,71% of the SADC share to 6,77% = an increase of 5,05%);
- Zimbabwe (from 2,54% of the SADC share to 7,53% = an increase of 4,99%);
- Botswana (from 1,71% of the SADC share to 4,16% = an increase of 2,45%); and
- Malawi (from 0,39% of the SADC share to 2,83% = an increase of 2,45%).

Other SADC countries, which have further increased their share of SADC water research, are:

- Namibia (from 0,61% of the SADC share to 1,81% = an increase of 1,21%);
- Mozambique (from 0,39% of the SADC share to 1,56% = an increase of 1,17%); and
- the DR Congo, Zambia and Swaziland increasing their share of SADC water research at a rate of less than 0,5% since the turn of the century (Table 7.1).

On the other hand, there are SADC countries where the contribution to SADC water research has declined. These are:

- South Africa (from 90,07% to 77,46% = a decline of 12,61%);
- Lesotho (from 0,39% to 0,31% = a decline of 0,08%); and
- Mauritius (from 0,99% to 0,31% = a decline of 0,69%).

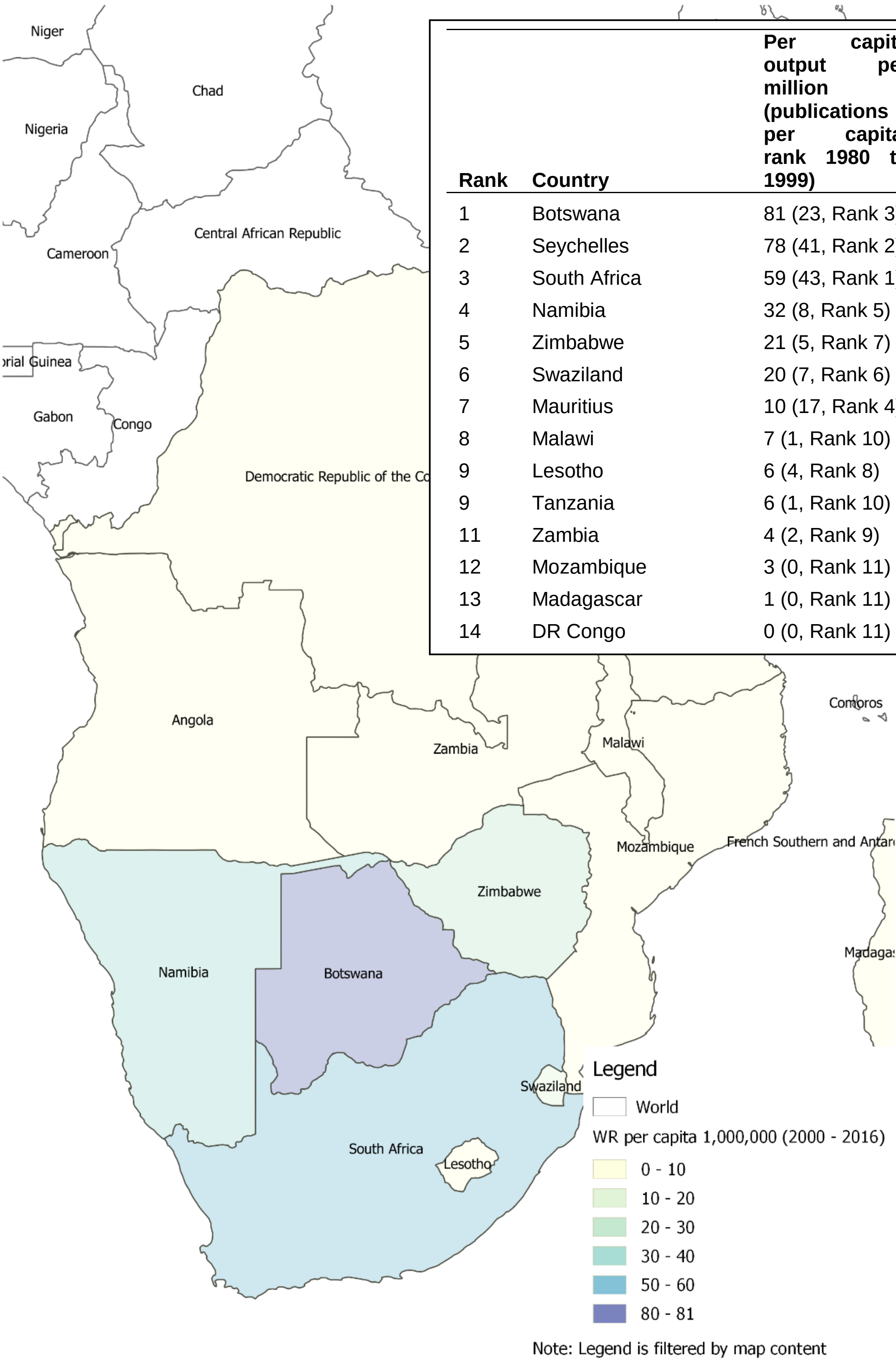
These results do not show the differences in resources each of the countries has, and for this reason, the normalised per capita output of water research for the different SADC countries is further presented in Table 7.1 and Figure 7.1. Here it becomes evident that before 2000, South Africa and Mauritius produced the highest number of per capita water research publications, with 43 and 41 publications per million population respectively, followed by Botswana (23 publications per million population), Mauritius (17 publications per million population) and Namibia (8 publications per million population). Since the turn of the century, the following countries have increased their water research publications as follows:

- Botswana (previously ranked 3rd) from 23 publications per million population to 81 per million population;
- Seychelles (previously ranked 2nd) from 41 publications per million population to 78 per million population;
- South Africa, (previously ranked 1st) from 43 publications per million population to 59 per million population;
- Namibia (previously ranked 5th) from 8 publications per million population to 32 per million population; and
- Zimbabwe (previously ranked 7th) from 5 publications per million population to 21 per million population.

Table 7.1: Water research as a share of research for the period 1980 to 1999 and 2000 to 2016

	1980 - 1999						2000 - 2016					
	Total Articles	**Water research publications**	**Water research as share of SADC**	**Water research as a share of total publications**	**Population average 1980–1999 ('000)**	**Per capita output water research per million (rank)**	**Total Articles**	**Water research publications**	**Water research as share of SADC (increase or decrease)**	**Water research as a share of total publications (increase or decrease)**	**Population average 2000–2016 ('000)**	**Per capita output water research per million (rank, rank: 1980–1999)**
Global	20 324 924	104 647		0,51%			33 380 262	209 673		0,63% (0,11%)		
African	209 068	2 907		1,39%			530 434	8 803		1,66% (0,27%)		
SADC	100 762	1 812		1,80%			216 463	3 917		1,81% (0,01%)		
South Africa	86 247	1 632	90,07%	1,89%			179 844	3 034	77,46% (-12,61%)	1,69% (-0,21%)		
SADC-ExSA	14 958	186	10,26%	1,24%			42 213	1 031	26,32% (16,06%)	2,44% (1,20%)		
Detail of SADC countries												
Botswana	1 014	31	1,71%	3,06%	1,367	23 (3)	4 245	163	4,16% (2,45%)	3,84% (0,78%)	2,012	81 (1, 3)
Swaziland	233	6	0,33%	2,58%	0,834	7 (6)	623	24	0,61% (0,28%)	3,85% (1,28%)	1,206	20 (6, 6)
Zimbabwe	4 395	46	2,54%	1,05%	9,874	5 (7)	5 951	295	7,53% (4,99%)	4,96% (3,91%)	14,235	21 (5, 7)
Namibia	563	11	0,61%	1,95%	1,416	8 (5)	2 091	71	1,81% (1,21%)	3,40% (1,44%)	2,202	32 (4, 5)
Lesotho	235	7	0,39%	2,98%	1,599	4 (8)	413	12	0,31% (-0,08%)	2,91% (-0,07%)	2,047	6 (9, 8)
Mozambique	402	7	0,39%	1,74%	14,289	0 (11)	2 554	61	1,56% (1,17%)	2,39% (0,65%)	24,010	3 (12, 11)
Tanzania	3 393	31	1,71%	0,91%	25,855	1 (10)	11 632	265	6,77% (5,05%)	2,28% (1,36%)	45,828	6 (9, 10)
Malawi	1 312	7	0,39%	0,53%	8,761	1 (10)	5 309	111	2,83% (2,45%)	2,09% (1,56%)	15,050	7 (8, 10)
South Africa	86 247	1632	90,07%	1,89%	37,628	43 (1)	179 844	3 034	77,46% (-12,61%)	1,69% (-0,21%)	51,488	59 (3, 1)
Seychelles	109	3	0,17%	2,75%	0,073	41 (2)	484	7	0,18% (0,01%)	1,45% (-1,31%)	0,090	78 (2, 2)
Mauritius	327	18	0,99%	5,50%	1,068	17 (4)	1 850	12	0,31% (-0,69%)	0,65% (-4,86%)	1,235	10 (7, 4)
Zambia	1 720	18	0,99%	1,05%	8,052	2 (9)	3 821	51	1,30% (0,31%)	1,33% (0,29%)	13,825	4 (11, 9)
Madagascar	21	0	0,00%	0,00%	11,833	0 (11)	2 905	13	0,33% (0,33%)	0,45% (0,45%)	20,877	1 (13, 11)
DR Congo	1 248	3	0,17%	0,24%	35,686	0 (11)	1 797	19	0,49% (0,32%)	1,06% (0,82%)	64,257	0 (14, 11)
Angola	101	0	0,00%	0,00%	12,397	0 (11)	656	1	0,03% (0,03%)	0,15% (0,15%)	23,207	0 (14, 11)

Source: Clarivate Analytics™ Web of Science™. For the calculation of per capita output: Worldometers (www.Worldometers.info) Elaboration of data by United Nations, Department of Economic and Social Affairs, Population Division. World Population Prospects: The 2017 Revision. (Medium fertility variant). Note: SADC-ExSA countries refer to all SADC countries, excluding South Africa.



Rank	Country	Per capita output per million (publications per capita, rank 1980 to 1999)
1	Botswana	81 (23, Rank 3)
2	Seychelles	78 (41, Rank 2)
3	South Africa	59 (43, Rank 1)
4	Namibia	32 (8, Rank 5)
5	Zimbabwe	21 (5, Rank 7)
6	Swaziland	20 (7, Rank 6)
7	Mauritius	10 (17, Rank 4)
8	Malawi	7 (1, Rank 10)
9	Lesotho	6 (4, Rank 8)
9	Tanzania	6 (1, Rank 10)
11	Zambia	4 (2, Rank 9)
12	Mozambique	3 (0, Rank 11)
13	Madagascar	1 (0, Rank 11)
14	DR Congo	0 (0, Rank 11)

Figure 7.1: MAP: Per capita output of water research in SADC countries (Publications per million) 2000 to 2016

Source: Clarivate Analytics™ Web of Science™.

From the analysis, it is evident that water research on the African continent has increased in general, as a share of global water research. For most SADC countries, there has been an increase in water research since 2000. When considering the per capita research output, countries such as Botswana, Seychelles, South Africa, Namibia and Zimbabwe, have consistently published the highest number of articles, given the population in the respective countries.

The increases and declines in water research in some SADC countries, further relate to the relative effort SADC countries devote to water research, which is discussed in more detail in the next section.

7.2.2 The relative effort SADC countries devote to water research

The results of an activity index (AI) calculation are presented in Table 7.2 and Figure 7.2 (refer to section 5.3.2.2 of this document for a detailed description on the calculation of the AI). The AI provides an indication of the relative effort or intensity a country devotes to a research field (Frame, 1977; Schubert & Braun, 1986). For this study, the AI was calculated as the water research share of a country (or group of countries, such as SADC) of the total publication output across all research fields, divided by the water research share of a larger pool of publication output in all science fields (see for example Pouris & Ho, 2013).

In Table 7.2, the relative effort African and SADC countries devoted to water research between 1980 and 2016, in relation to African and global research, is presented. Again, such a long period could mask changes over time, and for this reason, data are presented for the period before and after 2000. This also coincides with the start of the implementation period of the WARFSA in 1999, and, as part of the aims of this study, could provide some indication of a contribution the WARFSA programme made. In addition, the AI scores for South Africa and SADC countries excluding South Africa (SADC-ExSA) are presented. An index of above one indicates an effort above average, with an index below one indicating effort below the average (see Frame, 1977). Where the AI is equal to one, it would indicate that the effort by the country corresponds with the larger pool of research effort.

Table 7.2: The relative effort SADC countries devote to water research compared to Africa and the world (1980–2016)

	1980 to 1999			2000 to 2016		
	Global water research AI	**Africa water research AI**	**SADC water research AI**	**Global water research AI**	**Africa water research AI**	**SADC water research AI**
Global publications	1,0			1,0		
African publications	2,7	1,0		2,6	1,0	
SADC publications	3,5	1,3	1,0	2,9	1,1	1,0
South Africa publications	3,7	1,4	1,1	2,7	1,0	0,9
SADC-ExSA publications	2,4	0,9	0,7	3,9	1,5	1,3

Source: Clarivate Analytics™ Web of Science™

From Table 7.2, it is evident that the field of water research is one of the stronger fields of scientific production for the SADC countries compared to other countries in the world with AI scores of 2,7 and 2,6 before and after 2000. The same applies for SADC countries as a whole when compared to Africa, although marginally more with AI scores of 1,3 and 1,1 before and after 2000. If one were to compare South Africa and other SADC countries in the region, South Africa have in general, devoted more in-country effort to water research than SADC-ExSA countries before 2000, when compared to global, African and SADC water research effort. Following the turn of the century, SADC-ExSA countries however increased their relative effort on water research to higher levels than South Africa when compared to global, African and SADC regional effort. This phenomenon is further illustrated in Figure 7.2, where the AI scores for water research of individual SADC countries are presented for the periods 1980–1999 and 2000–2016 to indicate changes over time.

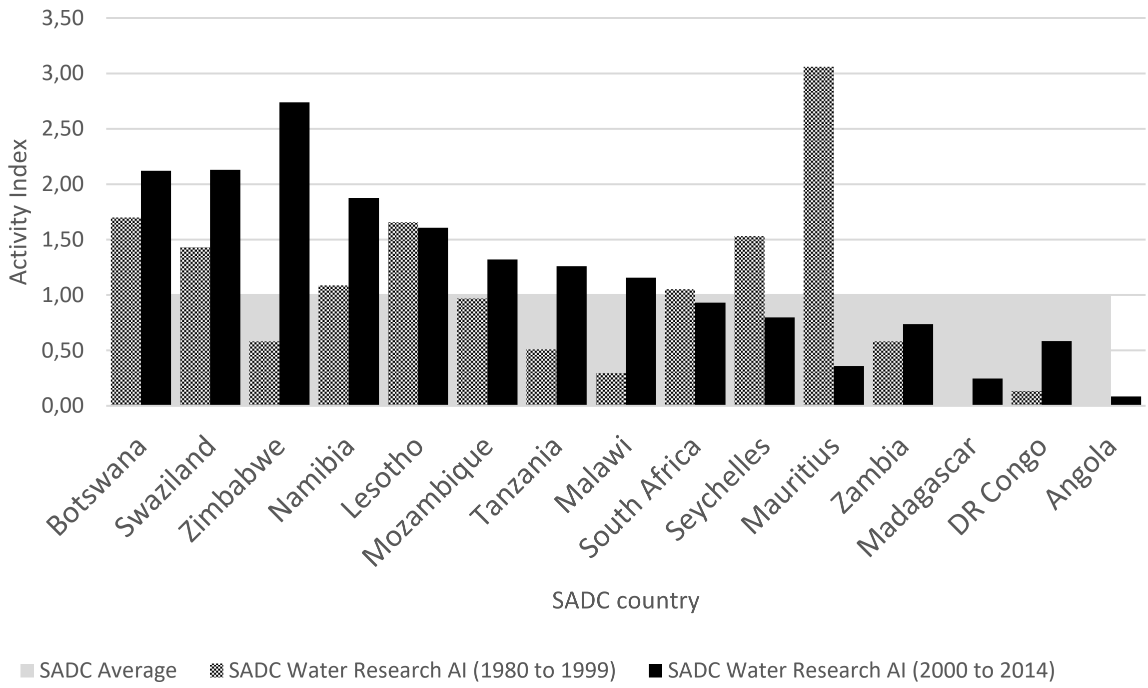


Figure 7.2: The relative effort SADC countries devote to water research (1980–2016)

Source: Clarivate Analytics™ Web of Science™

In Figure 7.2, the AI scores for water research of SADC countries are presented for the period 1980–2016 as they compare with all SADC countries, with data presented for between 1980 and 1999 and between 2000 and 2016 to indicate changes over time. In Figure 7.2, it is evident that countries, such as Botswana, Swaziland, Namibia and Lesotho, have consistently devoted more effort to water research in their countries than the SADC average. On the other hand, countries such as Zambia, Madagascar and Angola have devoted less in-country effort to water research in their countries than the SADC countries. Moreover, since 2000, countries, such as Botswana, Swaziland, Zimbabwe (significantly), Namibia (also significantly), Mozambique, Tanzania, Malawi, Zambia, Madagascar, the Democratic Republic of Congo and Angola, devoted more in-country effort to water research than before 2000. There have also been countries which devoted less in-country effort to water research after 2000 than before 2000, such as Lesotho and South Africa (both only marginally), with the island states of Seychelles and Mauritius devoting significantly less in-country effort after 2000 to water research than to other research fields.

From the discussions above, it is evident that one can conclude the following:

1. Overall, between 1980 and 2000, African countries have been more active in the production of water research publications compared to the rest of the world, with SADC countries even more active in water research than their counterparts on the continent as a whole.

2. Over the same period, SADC countries have recorded higher scores, thus in-country effort, in the AI for water research than the rest of the world and Africa.
3. In the SADC region, we also need to distinguish between those countries that have consistently been more active between 1980 and 2016 in terms of in-country water research than the SADC average, such as Botswana, Swaziland, Namibia and Lesotho.
4. There have also been SADC countries, such as Zambia, Madagascar and Angola, who have consistently been less active than the SADC average in terms of in-country water research in the period 1980–2016.
5. In some SADC countries, such as Botswana, Swaziland, Zimbabwe (significantly), Namibia (also significantly), Mozambique, Tanzania, Malawi, Zambia, Madagascar, the Democratic Republic of Congo and Angola, the AI score has increased, reflecting an increased focus on water research publications since 2000 as opposed to other research fields.
6. There are also SADC countries, such as Lesotho, South Africa (both marginally), Seychelles and Mauritius, where the AI score has mostly decreased since 2000, indicating a significant decrease in the activity of water research when compared to other research fields.

7.3 Conclusion

Through an overview of water research knowledge production in the SADC region, it is evident that water researchers on the African continent and in the SADC region, have mostly been more active when compared to global water research. Many SADC countries, such as Botswana, Swaziland, Namibia and Lesotho, have devoted more effort to water research than the SADC average, while most SADC countries have increased their water research activity since 2000. There have, however, been countries in the SADC region, which have indicated a decline in water research activity, such as Lesotho and South Africa (although marginally and still close to the SADC average in the case of South Africa), with Seychelles and Mauritius also indicating a significant decline in water research.

The study further highlighted the focus of private companies and individuals to produce patents as research outputs, possibly due to the potential economic value, as opposed to peer-reviewed articles, as universities and research institutions mostly contribute towards peer-reviewed articles.

With an overview of the knowledge produced in the SADC region now established, our focus can shift towards the bibliometric analysis of water publications from the SADC region. The following three chapters are divided into the analysis of water publications in all SADC countries (Chapter 8), followed by publications from South Africa (Chapter 9) and water publications in SADC countries excluding South Africa (Chapter 10).

Chapter 8

WATER PUBLICATIONS BY SADC COUNTRIES

8.1 Introduction

The purpose of Chapter 8 is to explain and discuss the knowledge production in the SADC water sector further, and to provide an in-depth bibliometric analysis of citation data, as extracted from the Clarivate Analytics™ Web of Science™ Core collection database. For a detailed discussion of the methodology used to extract the data, see section 5.3.1.

In this chapter, bibliometric data are analysed and presented in terms of:

- the **research output** in the SADC region and countries;
- **citation analysis** of research articles;
- the distribution of SADC water research articles in peer-reviewed **journals**; and
- the organisations that are providing financial **support** for the research in the SADC region.

8.2 Background

An analysis of the water research publications indicates that universities and other research institutions in the SADC region have recorded a steady increase in article production since the early 1990s (when fewer than 100 publications were published annually), to more than 230 publications published annually since 2010 (refer to Figure 8.1). Between 1980 and 2016, 5 729 water research publications[13] were produced by scholars affiliated to universities and research institutions in the SADC region. Since the 1980s, these publications have seen a steady increase, with total publications per year mostly below 100 publications per year up until 1998 (Figure 8.1). Since the early 2000s, annual publications grew to more than 100 per year, and more than 200 per year by the mid-2000s. The total number of water research publications in SADC countries has increased substantially to 345 in 2016, with more pronounced increases in the last few years since 2010.

Globally water research output has increased steadily since the early 1990s, with more than 13 400 water research publications published annually since 2010. The trend in publication output for the SADC region mostly mirrors worldwide trends.

[13] In extracting water research articles from the Clarivate Analytics™ Web of Science™ Core collection database, "ALL DOCUMENTS" and "ALL DOCUMENT TYPES" were selected.

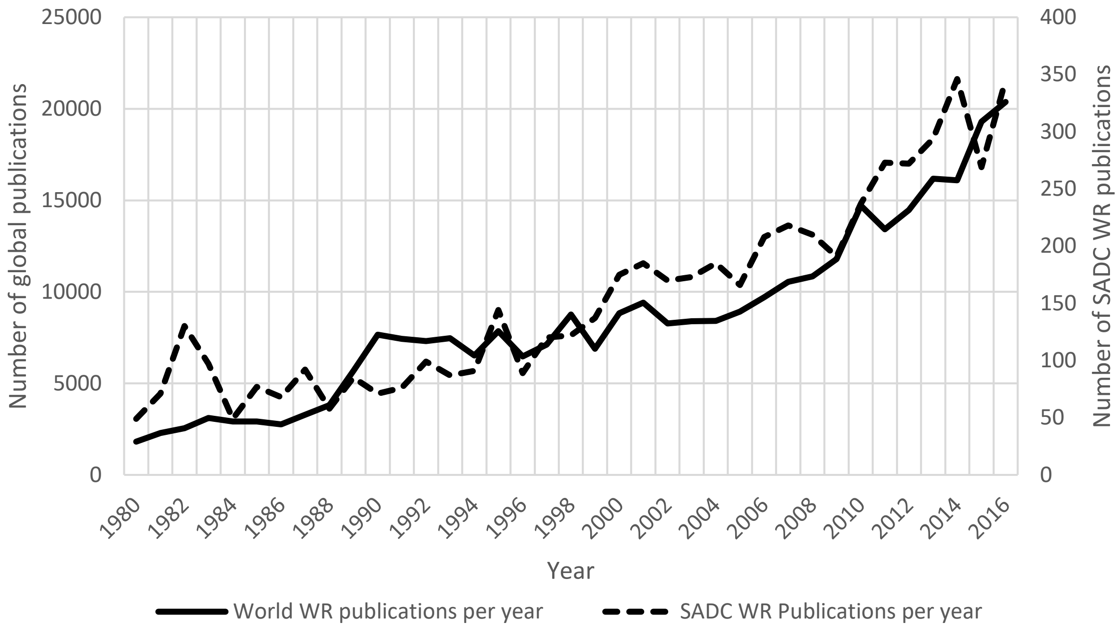


Figure 8.1: SADC vs rest of the world water research publications (1980–2016)

Source: Clarivate Analytics™ Web of Science™

It is therefore clear that water research has increased substantially over the years, both globally and in the SADC region, with the contributions from the SADC region expressed as a percentage presented in Figure 8.2. As a percentage of the world share, a decline is evident in the 1980s, from a high of 5,1% in 1982, to a low of 0,9% in 1990. Subsequently, the SADC world share of water research publications ranged between 2,2% and 1,4% since 2000, suggesting that the global contribution of the SADC region towards water research production has remained steady, even though there has been a general increase in the annual research production.

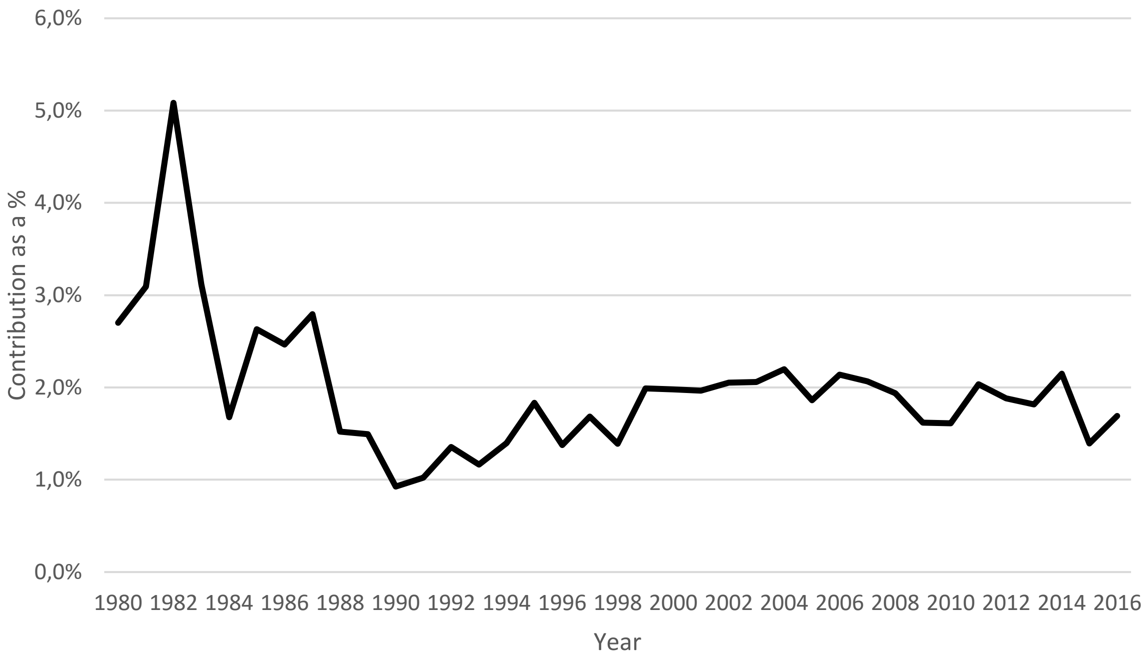


Figure 8.2: SADC world share (%) of water research publications (1980–2016)

Source: Calculated from data obtained from Clarivate Analytics™ Web of Science™

The annual growth rate (AGR) of water research provides an opportunity to gauge yearly increases or decreases in water research publications over a specific period. The AGR represents annual fluctuations, and for this reason, the average annual growth rate (AAGR) was calculated for three-year periods since 1980, with the results of the SADC three-year AAGR and the global three-year AAGR of water research presented in Figure 8.3. It is evident (Figure 8.3) that before the year 2000, major fluctuations occurred in the AAGR in both SADC and global water research. Since 2000, SADC water research and global water research followed the same trends in terms of growth and decline in AAGR, which can be attributed to a global and SADC regional growth in water research. Moreover, during the late 1990s, there was an increase in global awareness of integrated water research management (IWRM) (GWP-TAC, 2000), which could have contributed towards an increased focus on water and related research. More recently, the three-year AAGR of SADC water research has mostly been higher, albeit not much, than that of the rest of world, stabilising around 10% on a three-year average (see Figure 8.3).

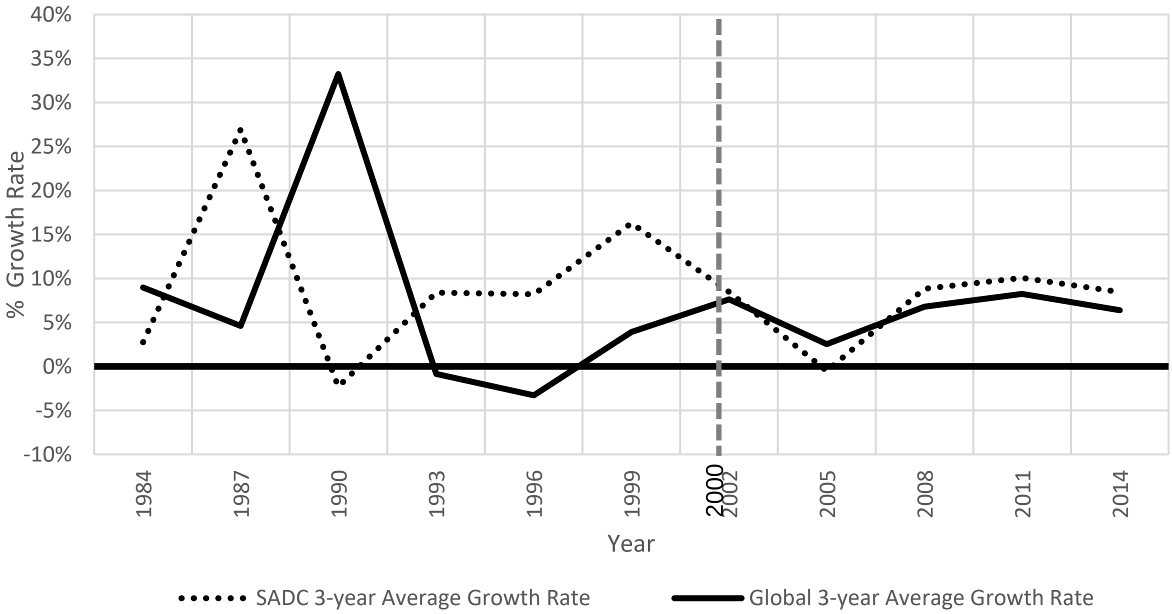


Figure 8.3: The three-year average annual growth rate (AAGR) of SADC vs. global water research since 1980

Source: Clarivate Analytics™ Web of Science™

It is thus evident that water research in the SADC region has increased along with the global water research output over the years. Our attention can now shift towards more detail on the individual country output, as highlighted in the next section.

8.3 Water research output from SADC countries

In the previous chapter, it was shown that SADC countries outside South Africa (referred to as SADC-ExSA countries) have experienced greater in-country effort in water research than South Africa, especially since 2000 (see section 7.2.1). One must keep in mind that this is in comparison with other science fields in the respective countries. Against a backdrop where researchers associated with universities and research institutions from South Africa have produced as much as 84% of all research outputs in the SADC region, South African researchers have also produced 81% of all water research articles published in the region between 1980 and 2016 (Table 8.1 and Figure 8.4). At the same time, researchers from SADC-ExSA countries have contributed 18% of the total number of publications across all research fields in the SADC region, and 26% of water research. Note that these figures do not necessarily add up to 100%, as 3% of water research publications and 2% of total publications had researchers from both South Africa and from institutions in the SADC region.

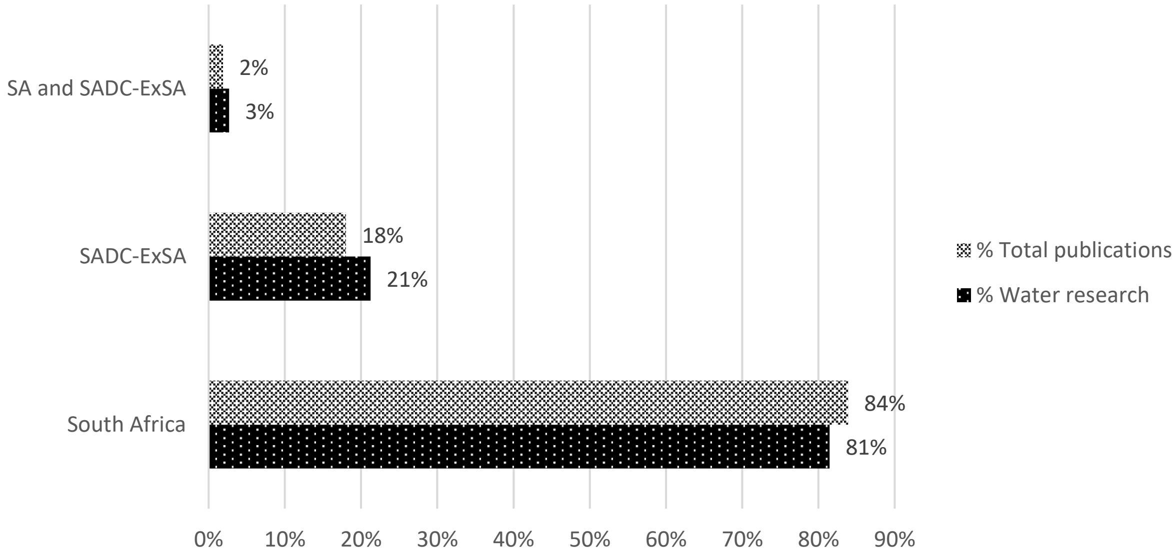
Table 8.1: Total and water research publications in SADC (1980–2016)

	Articles 1980–2016	Water research publications 1980–2016	All publications as a % of SADC publications	Water research as a % of SADC publications
SADC publications	317 225	5 729		
South African publications	266 091	4 666	83,9%	81,4%
SADC-ExSA publications	57 171	1 217	18,0%	26,1%
		Detail of SADC countries		
South Africa	266 091	4 666	83,9%	81,4%
Zimbabwe	10 346	341	3,3%	6,0%
Tanzania	15 025	296	4,7%	5,2%
Botswana	5 259	194	1,7%	3,4%
Malawi	6 621	118	2,1%	2,1%
Namibia	2 654	82	0,8%	1,4%
Zambia	5 541	69	1,7%	1,2%
Mozambique	2 956	68	0,9%	1,2%
Swaziland	856	30	0,3%	0,5%
Mauritius	2 177	30	0,7%	0,5%
Democratic Republic of Congo (DRC)	3 045	22	1,0%	0,4%
Lesotho	648	19	0,2%	0,3%
Madagascar	2 926	13	0,9%	0,2%
Seychelles	593	10	0,2%	0,2%
Angola	757	1	0,2%	0,02%

Source: Clarivate Analytics™ Web of Science™

Should one further consider the other 14 SADC countries where the publication records of South Africa are excluded (referred to as SADC-ExSA countries in this study), these countries have produced approximately one in five water research publications in the SADC region between 1980 and 2016. This highlights the overall dominance of human, infrastructure and financial resources of universities and research institutions in South Africa, as established earlier in this study. Water research output from South Africa is followed by Zimbabwe (6%), Tanzania (5,2%), Botswana (3,4%), Malawi (2,1%), Namibia (1,4%), Zambia (1,2%) and Mozambique (1,2%). The rest of the SADC countries, which include Swaziland, Mauritius, DRC, Lesotho, Madagascar, Seychelles and Angola, have all contributed less than 1% of water research in the SADC region between 1980 and 2016.

It is thus clear that water researchers from South African universities and research institutions produce the most publications by far, not just in terms of total research, but also in terms of water research in the SADC region. Individual countries, such as Botswana, Tanzania and Zimbabwe, have individually contributed between 3 and 6% each towards the region's water research, where the dominance of South African water research is greatly highlighted. In a sense, this should not be surprising with so many South African universities, research institutions and funding agencies, such as the Water Research Commission, contributing specifically towards water research, as highlighted in Chapter 6.



Note: Due to fractional counting, the co-authored articles were assigned to each country, resulting in the percentages not always counting up to 100%

Figure 8.4: Proportion of SADC water research (1980–2016)

Source: Clarivate Analytics™ Web of Science™

By further analysing the water research publications between 1980 and 2016 between South African and SADC-ExSA countries (Figure 8.5), the dominance of South African water research publications is again apparent, with major increases in publication output in recent years. SADC-ExSA countries have experienced an increase in water research publications in the early 2000s, after which it stabilised and again increased in recent years. However, as indicated earlier (see 7.2.2), SADC-ExSA countries have experienced a greater share of in-country water research, when water research is compared with other research fields in the same countries. Thus, we can conclude that, even though South African researchers as a whole produce far more water research than their counterparts in the SADC region, researchers from SADC-ExSA countries devote a larger effort to water research when compared with other research fields in their countries.

A detailed assessment of South African and SADC-ExSA water research will be reported in Chapters 9 and 10 respectively, providing a more detailed analysis on the publication trends.

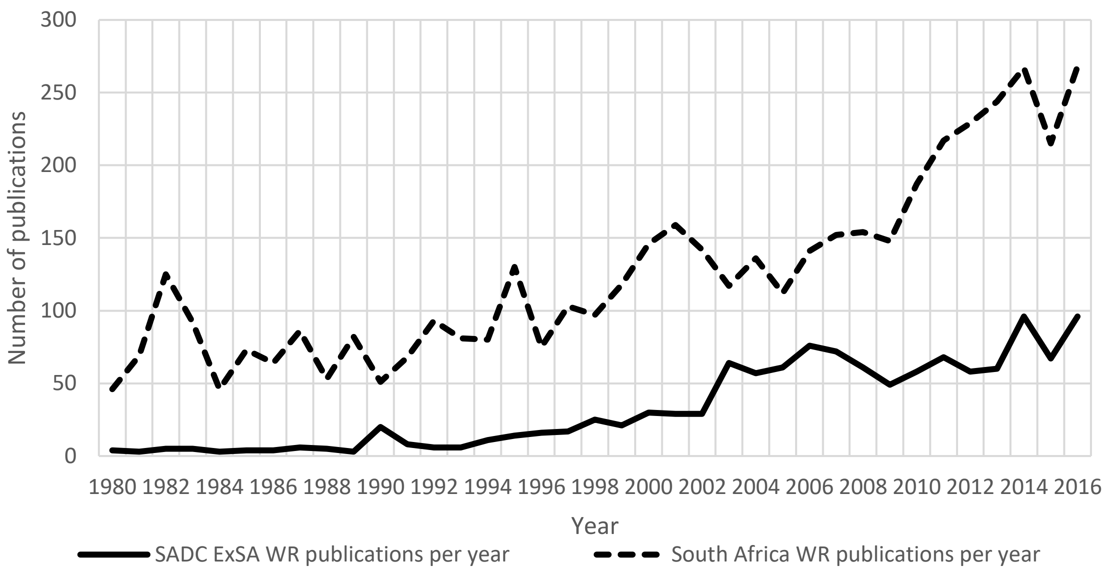


Figure 8.5: SADC water-related research output (1980–2016)

Source: Clarivate Analytics™ Web of Science™

Having presented the research output of water research in the SADC region, our focus can move to authorship trends in terms of water research in the region, which is presented in the next section.

8.3.1. Authorship of SADC water research

Through an analysis of publication data, it was found that 8 565 authors produced 5 729 water research articles published in the SADC region between 1980 and 2016, at an average rate of 1,5 authors per article. The average rate of authors per article provides only partial insight into the authorship trends, as it often occur that a relatively small number of authors publish a large number of publications in a particular research field, as originally observed by Alfred Lotka. In his research, Lotka (1926) determined that the number of authors producing *n* papers is proportional to $1/n^2$. This can be interpreted as the number of researchers producing one publication in a given period of time, is two orders of magnitude greater than the number of researchers publishing 10 papers in the same period of time, and four orders of magnitude greater than the number of researchers producing 100 publications (Katz & Martin, 1997). In his research, Lotka found that the proportion of researchers contributing a single publication, was around 60% (Coile, 1977)

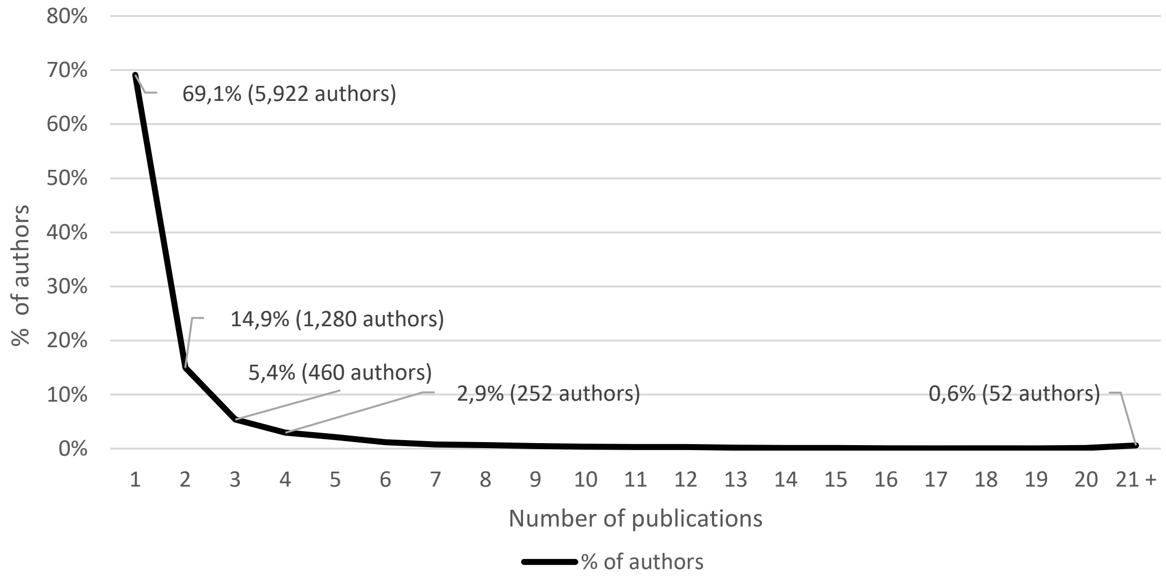


Figure 8.6: Distribution of SADC water research publications by number of publications between 1980 and 2016

Source: Clarivate Analytics™ Web of Science™

Figure 8.6 presents the distribution of water research publications in the SADC region between 1980 and 2016. It is evident that a very large number of authors (5 922 or 69,1%) produced one publication only, followed by 1 280 (14,9%), 460 (5,4%) and 252 (2,9%) authors who had two, three and four publications each. At the top end of the spectrum, there are 52 authors who produced more than 20 publications each. For the purpose of this study, these authors are referred to as ‘prolific water research publishing authors in the SADC region’.

It is further worthwhile assessing detailed publication and citation data of these 52 prolific water research publishing authors. This data include the number of publications per author (also presented as a percentage of total publications), the average citations per item, and the *h*-index of the author for the publications in this research field. In addition, the number of times articles have been cited, the number of self-citing articles (further presented as a percentage of articles), and finally the institution and country of the researcher are presented in Table 8.2.

From Table 8.2 it is evident that researchers such as Prof. George Ekama and Prof. Mark Wentzel (both from the University of Cape Town [UCT]), produced the highest number of water research publications between 1980 and 2016, with 155 and 112 articles respectively. In addition, several researchers who might not have published as many articles as the top researchers, are highly cited, such as Prof. Dold from UCT, who had 21 publications, at an average citation rate of 59,1 per article, and Prof. GV Marais, also from UCT, who had 54 articles published at an average citation rate of 36,1 per article. Moreover, if one were to consider that all water research articles together were cited 53 736 times between 1980 and

2016, at an average citation rate of 9,4 per article, most of the researchers in Table 8.2 have been cited above the SADC average.

As a side note, it is interesting to note the influence co-authorship has on citation trends amongst researchers, especially when the co-authors are prolific authors who are highly cited. If one considers the 155 articles published by Prof. Ekama and the co-authors from the articles, it becomes evident that 66% of all articles authored and co-authored by Prof. Ekama, had been co-authored by Prof. Wentzel and 24% by Prof. Marais. From Table 8.2, it is further evident that Prof. Loewenthal, who had published 38 articles, had also co-authored 18 articles with Prof. Ekama, 16 articles with Prof. Wentzel and five articles with Prof. Marais. Given the high number of publications and citations of both Prof. Ekama and Prof. Wentzel, it becomes evident that such co-authorship most probably contributes to the relative high number of citations and the citation rate of both Prof. Marias and Prof. Loewenthal – 36,1 and 35,1 respectively. The same would apply for Dr Dold, who had 21 publications, and six articles (29%) and five co-authored articles (24%) with Prof. Ekama and Prof. Wentzel respectively. The 21 published articles by Dr Dold have been cited 1 241 times at a citation rate of 59,1 since publication. Incidentally, these researchers are all from the University of Cape Town and are associated with the research unit. They collaborate on research related to a specific topic to which they all contribute. Making use of VOSViewer®,[14] the co-authorship network at UCT becomes even more evident, as presented in Figure 8.7. Here, the strong co-authorship link between Prof. Ekama, Prof. Wenzel and Prof. Marais can be seen clearly by the thickness of the line between the researchers in the graphic.

In the next section, authorship collaboration in the SADC water sector is discussed in detail.

[14] VOSViewer ® is computer software used to visualise bibliometric networks.

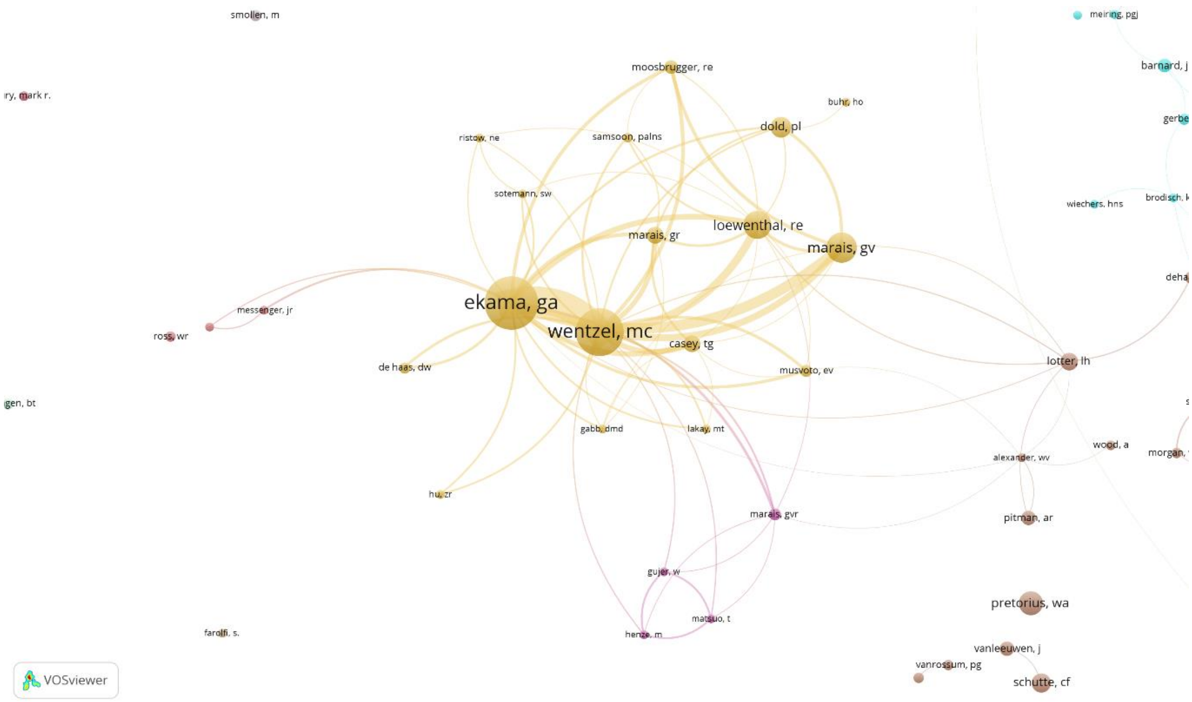


Figure 8.7: Bibliometric network map of research collaboration amongst researchers at the University of Cape Town (1980–2016)

Source: Clarivate Analytics™ Web of Science™

Table 8.2 further indicates the *h*-index of the prolific researchers in the SADC water sector. The *h*-index is a computable index, which provides an indication of the importance, and broad impact of a scientist's cumulative research contribution and could be used to provide a measure to compare different researchers (Hirsch, 2005). See section 5.3.2.1 for a more detailed explanation of the *h*-index. From Table 8.2, it is evident that only four researchers had a relatively high *h*-index of more than 20, meaning that those researchers had published 20 articles that had been cited more than 20 times – these authors being Prof. George Ekama, Prof. Mark Wentzel, Prof. GV Marais (all from UCT) and Prof. Dennis Hughes from Rhodes University (RU). In the case of Prof. Ekama, an *h*-index of 33 indicates that he had published 33 articles that were cited more than 33 times.

The self-citation rate of the prolific publishing authors is also presented in Table 8.2. These indicate that the average self-citation rate amongst the prolific authors is 8% and below the self-citation rate of SADC, which is 4,5%.[15] Considering the data in Table 8.2, it becomes evident that many of the top publishing authors are above the average self-citation rate, with some two and three times above the average self-citation rate. Studies have shown that self-citations could influence the *h*-index of researchers (Bartneck & Kokkelmans, 2011; Hirsch,

[15] An updated analysis of SADC water research articles based on the same query parameters for this study was conducted in December 2017, indicating that the average self-citation rate for water research articles in SADC at that stage, was 4,5%.

2005; Zhivotovsky & Krutovsky, 2008). Given the discussion in the previous sections relating to the *h*-index of the prolific researchers and research co-authorship affecting citation trends, it would be interesting for future research to assess how the *h*-index of the prolific authors was influenced through self-citation.

Finally, Table 8.2 provides the organisation and country of researchers who had more than 20 publications in the SADC region, which were dominated by researchers from South African institutions, such as the University of Cape Town (UCT), the University of Pretoria (UP), the University of KwaZulu-Natal (UKZN) and the Council for Scientific and Industrial Research (CSIR), who regularly feature amongst the top researchers. On the other hand, it is evident that researchers from other SADC countries only appear six times amongst researchers who have produced more than 20 water research articles in the SADC region. The researchers from the SADC region were:

- Prof. Innocent Nhapi (from Zimbabwe ranked 19th);
- Dr. David Love (ranked 37th);
- Prof. Dominic Mazvimavi and Dr Hodson Makurira (ranked 43rd and 44th respectively and associated with the University of Zimbabwe (UZ) and University of the Western Cape [UWC] in South Africa[16]); and
- Dr. Zvikomborero Hoko from UZ (ranked 50th).

Table 8.2 further list researchers from countries outside the SADC region, who have co-authored research articles with researchers from the SADC region, with Prof. Pieter van der Zaag from the Delft University of Technology/UNESCO IHE[17] (International Institute for Hydraulic and Environmental Engineering) in the Netherlands (ranked 25th).

[16] Prof. Dominic Mazvimavi is originally from Zimbabwe, but now works at UWC.

[17] It should be noted that in 2017, the UNESCO IHE changed its name back to IHE Delft Institute for Water Education. As this date fall outside the study period of this thesis, all references to UNESCO IHE was kept (IHE Delft Institute for Water Education, 2017).

Table 8.2 : Researchers who had more than 20 water research publications in the SADC region: 1980–2016

Rank	Authors	Publications	% of 8 568 publications	Average citations per item	Times cited	Self-citations	Self-citations as % of articles	*h*-index	Organisation	Country
1	EKAMA GA	155	2,5	26,5	4 105	758	18,5%	33	UCT	South Africa
2	WENTZEL MC	112	1,9	30,6	3 428	472	13,8%	29	UCT	South Africa
3	HUGHES DA	103	1,6	15,0	1 547	292	18,9%	21	RU	South Africa
4	BUCKLEY CA	103	1,5	11,6	1 192	28	2,3%	17	UKZN	South Africa
5	MAMBA BB	68	1,2	6,3	429	40	9,3%	12	UJ	South Africa
6	GRABOW WOK	67	1,2	16,0	1 074	57	5,3%	18	UP	South Africa
7	CLOETE TE	64	1,1	10,8	693	40	5,8%	15	SU and UP	South Africa
8	HAARHOFF J	62	1,1	7,5	463	40	8,6%	13	UJ	South Africa
9	SCHOONBEE HJ	54	0,9	7,1	386	107	27,7%	11	UL	South Africa
10	MARAIS GV	54	0,7	36,1	1 947	65	3,3%	22	UCT	South Africa
11	JEWITT GPW	45	0,7	8,5	382	33	8,6%	13	UKZN	South Africa
12	KFIR R	39	0,6	10,1	392	22	5,6%	10	CSIR and WRC	South Africa
13	LOEWENTHAL RE	38	0,6	35,1	1 335	58	4,3%	17	UCT	South Africa
14	XU YX	38	0,6	4,6	174	22	12,6%	7	UWC	South Africa
15	MAREE JP	37	0,6	10,9	404	27	6,7%	13	CSIR and WRC	South Africa
16	STEPHENSON D	34	0,6	7,6	259	8	3,1%	9	WITS	South Africa
17	VAN ZYL JE	33	0,6	12,7	420	53	12,6%	10	UJ and UCT	South Africa
18	VAN KOPPEN B	32	0,6	7,7	247	26	10,5%	9	IWMI	South Africa**
19	NHAPI I	32	0,5	5,1	162	14	8,6%	7	CUT, UZ and UR	Zimbabwe and Rwanda
20	MOMBA MNB	32	0,5	13,9	446	27	6,1%	13	TUT	South Africa
21	SCHULZE RE	31	0,5	12,7	394	16	4,1%	12	UP	South Africa
22	PRINSLOO JF	31	0,5	7,1	219	80	36,5%	9	UL	South Africa
23	JAMES CS	30	0,5	15,3	458	23	5,0%	10	UJ	South Africa
24	BROUCKAERT CJ	30	0,5	9,4	281	6	2,1%	9	UKZN	South Africa
25	VAN DER ZAAG P	29	0,5	10,1	293	25	8,5%	12	Delft–UT and UNESCO IHE	Netherlands
26	PRETORIUS WA	29	0,5	10,2	297	18	6,1%	10	UP	South Africa
27	PEGRAM GGS	29	0,5	20,1	584	27	4,6%	16	UKZN	South Africa

Rank	Authors	Publications	% of 8 568 publications	Average citations per item	Times cited	Self-citations	Self-citations as % of articles	*h*-index	Organisation	Country
28	VENTER SN	28	0,5	16,1	451	14	3,1%	10	UP	South Africa
29	SANDERSON RD	27	0,5	10,0	271	21	7,7%	10	SU	South Africa
30	MSAGATI TAM	27	0,5	4,1	110	6	5,5%	6	UJ	South Africa
31	FATOKI OS	26	0,5	17,0	442	18	4,1%	13	CPUT and UV	South Africa
32	BUX F	26	0,5	17,5	454	13	2,9%	13	DUT	South Africa
33	ANNANDALE JG	26	0,4	10,2	265	34	12,8%	10	UP	South Africa
34	WEPENER V	25	0,4	9,1	227	11	4,8%	9	NWU and UNIZULU	South Africa
35	VAN RENSBURG LD	25	0,4	4,1	102	23	22,5%	6	UFS and CSIR	South Africa
36	NGILA JC	24	0,4	5,8	139	2	1,4%	6	UJ and UKZN	South Africa
37	LOVE D	24	0,4	16,3	390	39	10,0%	13	WaterNet and UZ	Zimbabwe
38	ASHTON PJ	24	0,4	13,6	326	8	2,5%	11	CSIR and WRC	South Africa
39	BRITZ TJ	23	0,4	8,8	202	31	15,3%	9	SU	South Africa
40	WIECHERS HNS	22	0,4	0,7	16	3	18,8%	3	WRC	South Africa
41	TUTU H	22	0,4	2,8	61	4	6,6%	4	WITS	South Africa
42	SMITHERS JC	22	0,4	10,1	223	16	7,2%	7	UKZN	South Africa
43	MAZVIMAVI D	22	0,4	13,9	305	11	3,6%	9	UZ, UWC, UB	Zimbabwe and South Africa
44	MAKURIRA H	22	0,4	8,3	183	17	9,3%	10	UZ and UWC	Zimbabwe and South Africa
45	ADAMS JB	22	0,4	10,7	236	20	8,5%	8	NMMU	South Africa
46	WALKER S	21	0,4	9,2	194	7	3,6%	10	UFS	South Africa
47	TAIGBENU AE	21	0,4	12,5	263	21	8,0%	8	WITS	South Africa
48	SCHUTTE CF	21	0,4	17,2	361	1	0,3%	8	UP	South Africa
49	SCHOEMAN JJ	21	0,4	13,4	282	9	3,2%	9	CSIR and UP	South Africa
50	HOKO Z	21	0,4	11,3	238	16	6,7%	9	UZ	Zimbabwe
51	EHLERS MM	21	0,4	15,4	323	9	2,8%	10	UP	South Africa
52	DOLD PL	21	0,4	59,1	1 241	23	1,9%	11	UCT	South Africa
	TOTAL	1995	33,2		29 316	2761				
	AVERAGE			13,2	563,8	53,1	8% (SADC 4,5%)	11,5		

Note: Where researchers from other countries other than South Africa are indicated, those typically indicate research collaborations.

** IMWI is an international research institute, with offices in South Africa.

Source: Clarivate Analytics™ Web of Science™

Key:

CPUT – Cape Peninsula University of Technology

CSIR – Council for Scientific and Industrial Research

CUT – Chinhoyi University of Technology (Zimbabwe)

Delft–UT – Delft University of Technology

DUT – Durban University of Technology

IWMI – International Water Management Institute

NMMU – Nelson Mandela Metropolitan University[18]

NWU – North-West University

RU – Rhodes University

SU – Stellenbosch University

UB – University of Botswana

UCT – University of Cape Town

UFS – University of the Free State

UJ – University of Johannesburg

UKZN – University of KwaZulu-Natal

UL – University of Limpopo

UNIZULU – University of Zululand

UP – University of Pretoria

UR – University of Rwanda

UV – University of Venda

UWC – University of the Western Cape

UZ – University of Zimbabwe

WITS – University of the Witwatersrand

WRC – Water Research Commission

[18] It should be noted that in 2017, the Nelson Mandela Metropolitan University (NMMU) changed its name to Nelson Mandela University (NMU). As this date fall outside the study period of this thesis, all references to Nelson Mandela Metropolitan University (NMMU) was kept (NMU, 2017).

As evident from Table 8.2, researchers from the same institutions, such as UCT, UP, UKZN and UZ are present amongst the more prolific researchers in the SADC region. This could suggest research networks amongst these prolific researchers. By making use of VOSviewer® data visualization software, publication data of the water researchers present in Table 8.2 was analysed, with the results presented in Figure 8.8. Here the co-authorship collaborations between researchers such as Prof. Ekama (University of Cape Town), Prof. Buckley (University of Kwa-Zulu Natal), Prof. Grabow and Prof. Cloete (University of Pretoria), Prof. Hughes (Rhodes University) and the related associations with Prof. Nhapi, Dr. Love (from Zimbabwe) and Prof. van der Zaag (from the Netherlands) becomes evident.

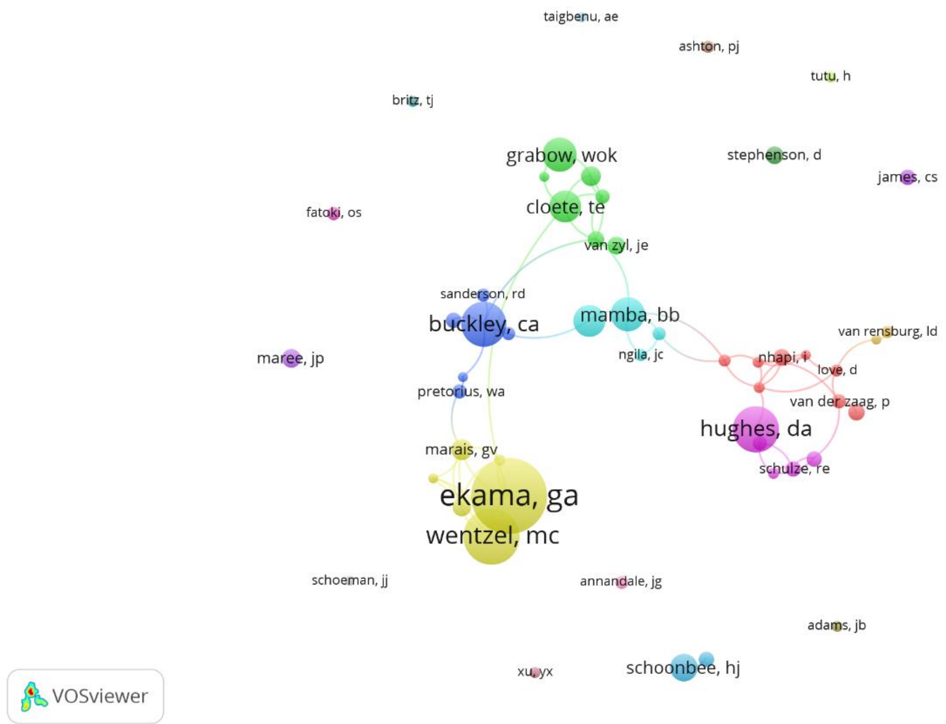


Figure 8.8: Author network visualisation of SADC water researchers who have published more than 20 publications each (1980–2016)

Source: Clarivate Analytics™ Web of Science™

From the analysis, it is clear that of the water research articles published between 1980 and 2016 in the SADC region, 5 922 (69%) of the authors have contributed one article. As can be expected, based on Lotka's observations, there is a dramatic decline of authors contributing two articles, with 1 280 authors (14,9%) contributing two articles. A further 52 authors (0,6%) contributed more than 20 articles each. These researchers were predominantly from South Africa, and institutions such as UCT, UP, UKZN and the CSIR regularly featuring amongst the top publishing researchers. Moreover, only a handful of researchers from other SADC countries are amongst the top publishing authors, predominantly from Zimbabwe, and only a few researchers constantly produce research articles that are cited regularly in the SADC water sector.

Having presented the water researchers in the SADC region who have published more than 20 publications, it is clear that these prolific researchers often collaborate with other researchers to form networks (refer to Figure 8.8). These networks of researchers by co-authoring publications, often due to a joint research focus, as we have seen with the water research network at the University of Cape Town as presented in this section.

The following section aims to present authorship collaboration trends through an analysis of the number of authors per publication over time, and an overview of countries where researchers in the SADC region co-author publications.

8.3.2. Co-publication trends in SADC water research publications

Research collaboration can often manifest in co-authorship of articles. Considering all publications in the SADC region, Boshoff (2009) found a notable and steady increase in articles published in the SADC region, starting in the early to mid-1990s, probably attributed to the change in the South African democracy by the mid-1990s, leading to other SADC countries collaborating with South African researchers (Boshoff, 2009b:493). The same study found that when excluding South African articles from the data, the percentage of publications started to increase in the mid- to late 1980s, however at intervals by the end 1980s, the mid-1990s and the early 2000s. In addition, Boshoff (2010) further confirms a major declining trend in single-authored articles between the periods 1975 and 1978 and between 2005 and 2008 in all SADC countries. These results are in line with findings by Pouris and Ho (2013), who assessed the research emphasis and collaboration from African countries between 2007 and 2011. In their study, it was found that the share of single-authored articles from African countries was mostly below 10%. Only Egypt and Botswana had a share of 16% and 10% respectively.

8.3.2.1 Number of authors per publication

By focussing on water research in the SADC region, single-authored articles and multiple-authored articles up to five authors have dominated water research publications since the 1980s (Figure 8.9). In the mid-1980s, up to 47% of water research articles were single-authored articles. However, over time, a steady decline in single-authored articles occurred, which is in line with findings from previous studies (Boshoff, 2010a; Pouris & Ho, 2013). Articles with two authors have also declined over time, from a high of 47% in the mid-1990s, to 16% in 2016. Articles with three authors have steadily increased since the mid-1980s to a high of 35% in 2000, and remaining constant between 22% and 30% in recent years. Articles with four authors have also followed the same trend as articles with three authors, and steadily increased from 8% in the late 1990s to 22% in recent years. Articles with more than five authors have, however, increased since the early 1990s, from hardly any articles, to 27% in recent years. In 2016, publications with three or five and more authors, comprised 57% of all publications.

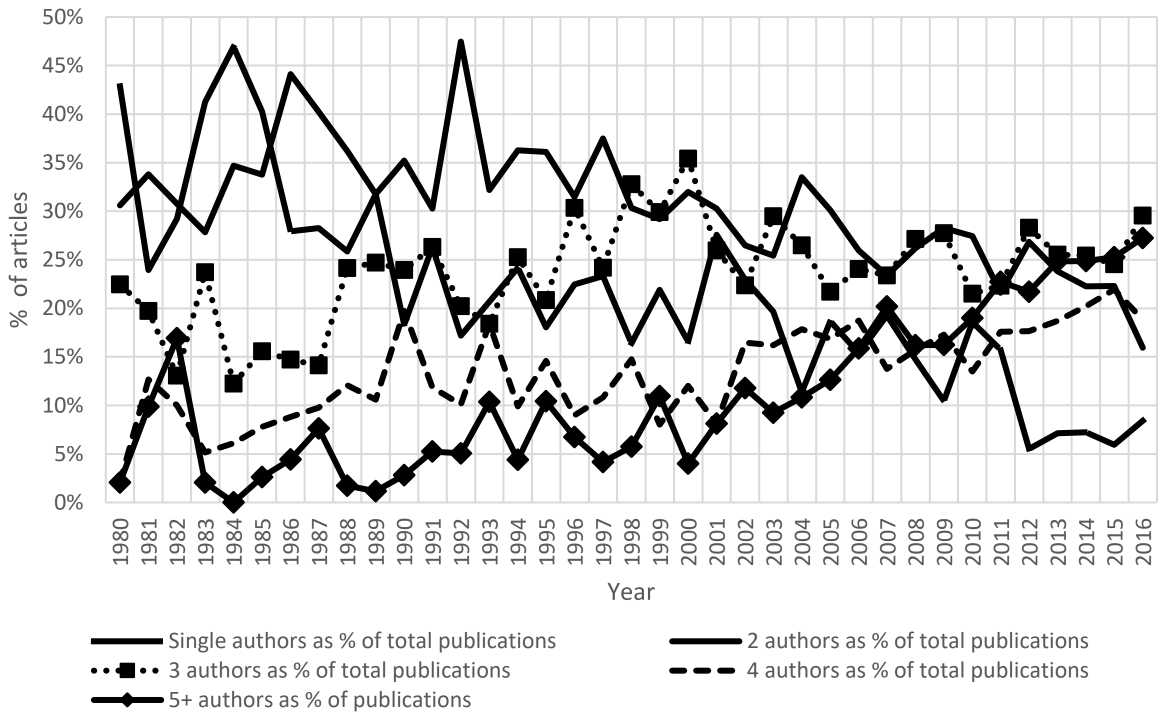


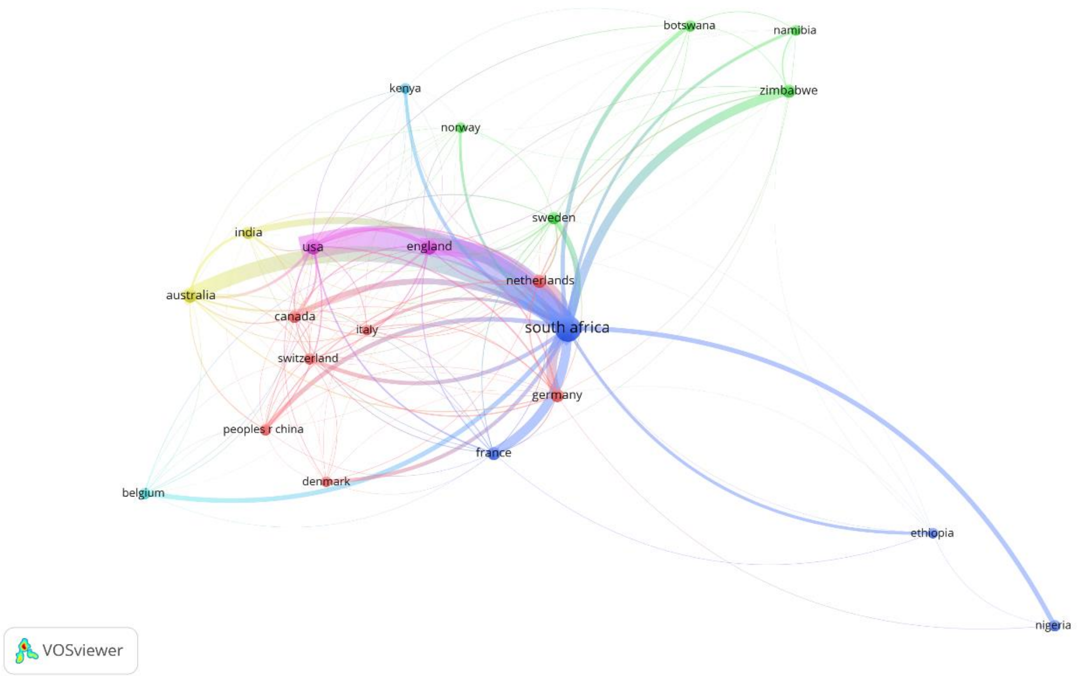
Figure 8.9: Co-authorship trends of SADC water research publications (1980–2016)

Source: Clarivate Analytics™ Web of Science™

From the section above, it becomes evident that water researchers in the SADC region tend to co-publish water research increasingly with multiple authors, and in many cases, with five and more authors per publication, with very few single-authored water research articles in recent years.

8.3.2.2 Co-authorship countries

With SADC water researchers co-publishing increasingly with other researchers in recent years, our attention shifts toward research collaboration at national level. Figure 8.10 provides and indicates visualisation of SADC water research between 1980 and 2016, with bibliometric data analysed making use of VOSviewer® software. In order to highlight the most prominent co-authorship collaborations between countries, bibliometric data were analysed making use of VOSViewer® software, with analysis parameters set at a minimum of 20 articles between countries. The figure graphically presents various aspects, where the countries presented indicate the most predominant countries with whom water researchers in the SADC region co-author publications. In addition, the thickness of the line between countries represents the relative extent of co-authorship. These elements are discussed in more detail in the next section.



Min count of articles between countries: 20

Figure 8.10: Country network visualisation: Co-authorship of water research in the SADC water sector (1980–2016)

Data source: Clarivate Analytics™ Web of Science™ and analysed with VOSViewer®

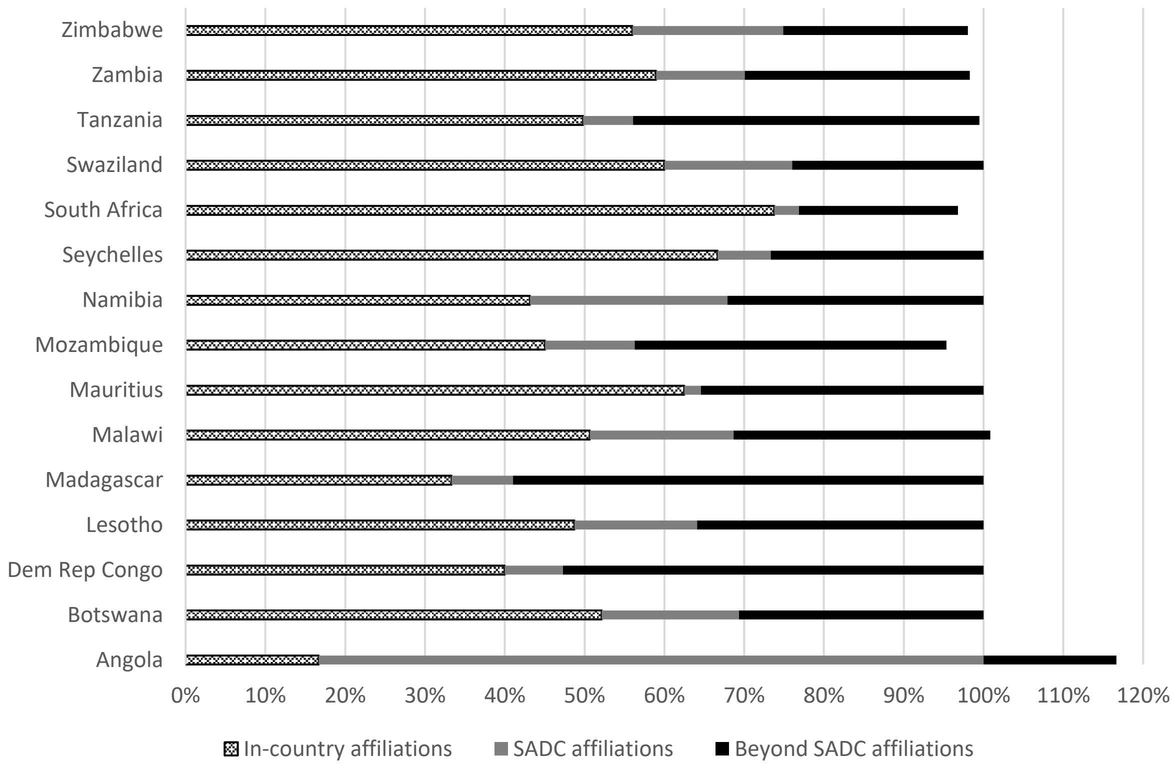
2. **Predominant co-authorship countries:** From Figure 8.10, it is evident that co-authorship of publications exists between water researchers from the SADC region and many countries around the world. For now, the countries are indicated, using a more detailed analysis, for South Africa in Chapter 9 and SADC-ExSA countries in Chapter 10. Prominent countries in the SADC region are South Africa, Zimbabwe, Botswana, Tanzania, Mozambique, Zambia, Namibia, Malawi, Swaziland and Mauritius. African countries beyond SADC are Uganda, Kenya, Ethiopia and Nigeria. Countries in North America are the United States and Canada, in Europe, countries are Norway, Sweden, Finland, Italy, Netherlands, Denmark, Germany, the United Kingdom (Scotland and England), Switzerland, Austria, France, Belgium and Spain. In Australasia, co-authorship exists with countries such as Australia, Japan, and the People's Republic of China.
3. **Predominant co-authorship associations (strength of country association):** The most prominent co-authorships exist between South Africa and other countries, such as the

United States, United Kingdom (England), the Netherlands, Zimbabwe, Germany, France, Canada, Nigeria, Belgium and the People's Republic of China. Other notable co-authorship collaborations are evident between the Netherlands and SADC countries such as Zimbabwe and Tanzania. Even though Figure 8.10 provides a visual indication of the extent of co-author collaboration between the SADC countries, it is limited in that it provides a relative indication through the thickness of the lines between the countries. In Chapter 9, a more detailed discussion will follow on the extent of South Africa's collaborations, and in Chapter 10, more detail on the rest of the SADC countries.

From the section above, it is evident that water research co-authorship collaboration with South Africa and other countries exist all over the world. Following South Africa, and more recently, other SADC countries such as Zimbabwe, Tanzania, Botswana, Malawi, Mozambique and to a lesser extent Zambia, Swaziland and Mauritius, water research co-authorship associations with other countries in the SADC and beyond have developed, most notably with the Netherlands. This finding can be corroborated by the strong support the Dutch Government has been providing for WaterNet over the years. (For more detail, refer to section 6.3.1 for a detailed discussion on WaterNet.)

8.3.2.3 Overview of individual SADC water research co-authorships collaboration

Having presented an overview of co-authorship collaborations between SADC countries and the rest of the world, our focus now shifts to the co-authorship affiliations for the 15 SADC countries. Do authors in SADC countries tend to co-author with fellow researchers from their own country, within the SADC region or beyond the SADC? In order to address these questions, Figure 8.11 provides the ratio of co-authored publications from the SADC region in terms of in-country affiliations, SADC affiliations and beyond-SADC affiliations. A detailed assessment of the co-author collaborations per individual SADC country is presented in Chapter 9 in the case of South Africa, and in Chapter 10 for SADC countries excluding South Africa.



Note: Due to fractional counting, the co-authored articles were assigned to each country, resulting in the percentages not always counting up to 100%. This means that co-authors could have had more than one affiliation in countries.

Figure 8.11: Distribution of co-authored water research publications in the SADC region and beyond (1980–2016)

Source: Clarivate Analytics™ Web of Science™

The results show that water researchers from most SADC countries tend to co-author with other researchers from their own country. Countries are Zimbabwe, Zambia, Swaziland, South Africa, Seychelles, Mauritius, Malawi and Botswana. In Tanzania, close to 50% water researchers have been affiliated with in-country researchers, and a large percentage was affiliated with countries beyond SADC (43%), while very few co-authors affiliated with institutions from other SADC countries (6%). South African water researchers have co-authored publications mostly with fellow researchers from South Africa (74%), followed by researchers from beyond SADC (20%) and then, to a limited extent, with other water researchers form the SADC region (3%). These findings are in line with findings of a previous a study by Pouris (2015:19). Moreover, much like South Africa, researchers in Mauritius and Seychelles have co-authored publications mostly with researchers from their own country, then beyond the SADC region and to a limited extent within the SADC region.

It is further evident from Figure 8.11, that there are SADC countries, which tend to co-author publications predominantly with researchers not from their own country. These countries are Namibia, Mozambique, Madagascar, Lesotho, the DRC and Angola. This can probably be attributed to the limited number of research institutions and researchers in these countries. Most of these countries tend to co-author publications with researchers beyond the SADC region, such as Madagascar (59%) and the DRC (53%), followed by Mozambique (39%), Lesotho (36%) and Namibia (32%).

Lastly, there are SADC countries that have co-authored a fair amount of publications with researchers from the SADC region. These countries are Namibia (25%), Zimbabwe (19%), Malawi (18%), Botswana (17%), Swaziland (16%) and Lesotho (15%). Angola is an anomaly, as the country has only had one water research publication with 9 out of the 14 authors affiliated with institutions in the SADC region. Moreover, some of the researchers have affiliations with institutions in the SADC region and also beyond SADC, which accounts for the fractural counting.

In conclusion, it is evident that overall, water researchers in the SADC tend to co-author with researchers from their own countries, then beyond SADC and lastly with researchers from other SADC countries (Figure 8.12). Moreover, when comparing South African water researchers with their counterparts in the SADC countries, it is evident that more researchers from SADC-ExSA countries tend to co-author water research publications with other in the SADC region, than South African researchers do.

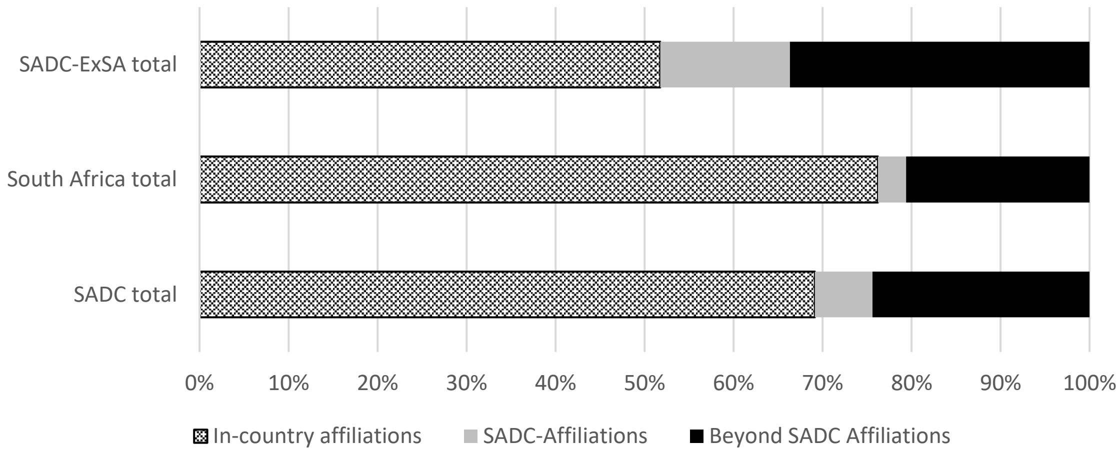


Figure 8.12: Relative regional and global distribution of co-author publications of water research in SADC (1980–2016)

Source: Clarivate Analytics™ Web of Science™

Having considered various aspects relating to the research output and authorship trends of water research emanating from universities and research institutions from the SADC region, in the following section, our focus now shifts towards the citation analysis of the publications.

8.4 Citation analysis of water research publications in all SADC countries

As mentioned earlier in this document (see 8.2), 5 729 water research articles have been published by researchers from universities and research institutions in the SADC region between 1980 and 2016. These articles have been cited 53 736[19] times, at an average rate of 9,38 times per article, with 75,74% of all water research publications cited over this period (Table 8.3 and Figure 8.13). Further analysis of the citation distribution of water research emanating from SADC countries, is presented in Table 8.3 and Figure 8.13, which indicate the publication and citation distribution in citation ranges and citation rates.

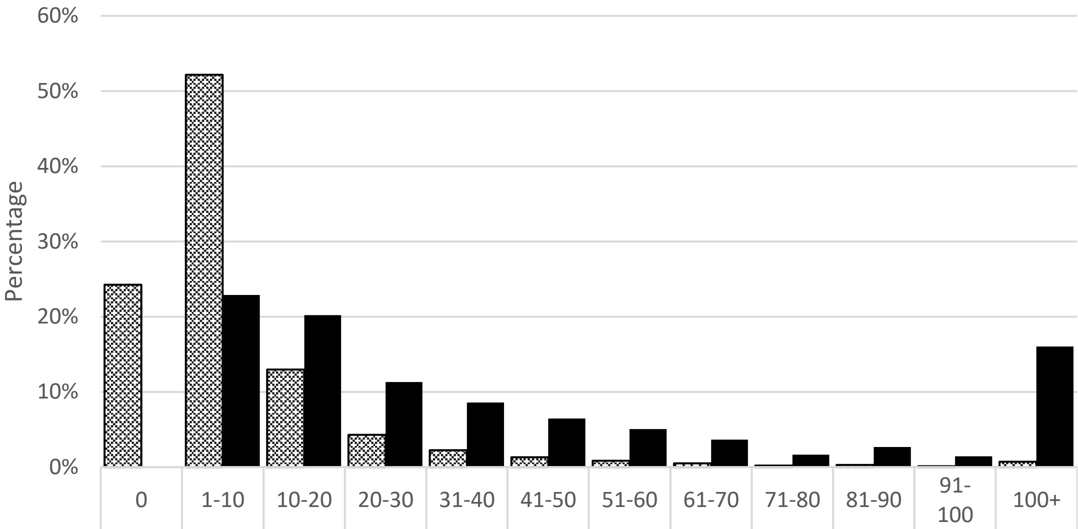
Table 8.3: Distribution of SADC water research publications and citations (1980–2016)

Citation range	Number of publications	% of publications	Number of citations	% of citations	Citation rate
0	1 390	24,26%	0	0	
1–10	2 988	52,16%	12 294	22,88%	4,11
10–20	743	12,97%	10 864	20,22%	14,62
20–30	246	4,29%	6 090	11,33%	24,76
31–40	130	2,27%	4 620	8,60%	35,54
41–50	76	1,33%	3 465	6,45%	45,59
51–60	49	0,86%	2 717	5,06%	55,45
61–70	30	0,52%	1 956	3,64%	65,20
71–80	12	0,21%	900	1,67%	75,00
81–90	17	0,30%	1 445	2,69%	85,00
91–100	8	0,14%	775	1,44%	96,88
100+	40	0,70%	8 610	16,02%	215,25
Total	**5 729**	**100%**	**53 736**	**100%**	
Average citation rate			**9,38**		

Source: Clarivate Analytics™ Web of Science™

The results show that 24% of water research articles in the SADC region published between 1980 and 2016, had never been cited, with most publications (52%) receiving between 1 and 10 citations at an average citation rate of 4,11 cites per article. There are however 40 articles, which account for less than 1% of all water research in the SADC region, which have been cited over 8 600 times at an average citation rate of 215,25 per article, accounting for 16% of all citations. Closer inspection of the articles reveal than three articles have been cited more than 500 times and one in particular, by Bosch and Hewlett (1982), has been cited over 1 000 times since its publication in 1982.

[19] Include self-citations



	0	1-10	10-20	20-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100	100+
% of publications	24,26%	52,16%	12,97%	4,29%	2,27%	1,33%	0,86%	0,52%	0,21%	0,30%	0,14%	0,70%
% of citations	0	22,88%	20,22%	11,33%	8,60%	6,45%	5,06%	3,64%	1,67%	2,69%	1,44%	16,02%

Figure 8.13: Distribution of SADC water research publications and citations (1980–2016)

Source: Clarivate Analytics™ Web of Science™

If one were to assess the average number of citations per article between 1980 and 2016 further on an annual basis, it becomes evident that there has been a steady increase in the average citation rate over the years (Figure 8.14). More recently, the number of water research articles has increased substantially, which resulted in a decline in the average number of citations per article.

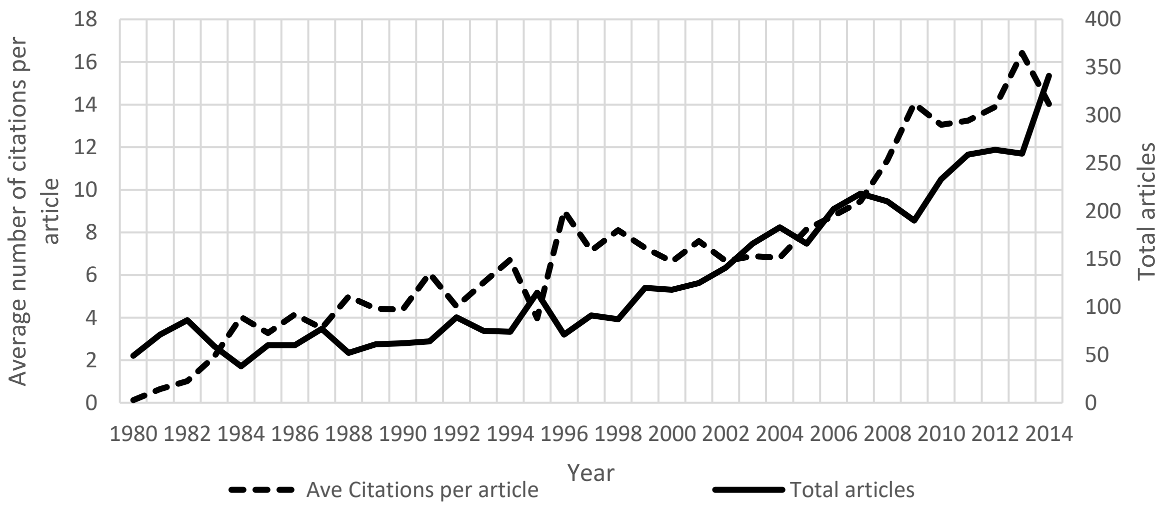


Figure 8.14: Average citations of SADC Water research articles in relation to the total number of articles published (1980–2014)

Source: Clarivate Analytics™ Web of Science™

8.4.1 Citation impact

The citation score and average citation rate provides an indication of the frequency at which an average article is cited. However, due to factors which include the differences amongst fields in the average number of cited references per publication, the degree to which references from other fields are cited, the average age of cited references, and considering that the number of citation always increase over time, citation scores are normalised by calculating the mean normalised citation score (MNCS) (Leydesdorff et al., 2011; Waltman et al., 2011). For a more detailed discussion on the MNCS, refer to section 5.3.2.1).

By analysing the citation data of water research in SADC, the average annual citation scores of water research in the SADC region is presented in Table 8.4 for the period between 1980 and 1999, and in Table 8.5 for the period between 2000 to 2016, with the annual distribution of the data further presented in Figure 8.15. In addition, the annual MNCS-values of water research in the SADC region are listed.

First, the annual citation scores are discussed (Figure 8.15), where it is evident that there has been a gradual increase in publications over the years, starting from 49 publications in 1980, and continuously less than 150 articles were published annually between 1980 and 1999. These articles were cited at an average rate of between 8,21 and 15,21 times annually, with a steady increase in the late 1990s. After 2000, the annual number of articles increased to above 150 publications per year, with the average citations increasing to 18,28 in 2003. After 2003, there has been a decline in the average number of citations, even if one were to consider that a time lag occurred in terms of when articles were published and when they were cited. One reason could be the increase in publications, and relatively fewer publications having significantly higher citations. This could be investigated further.

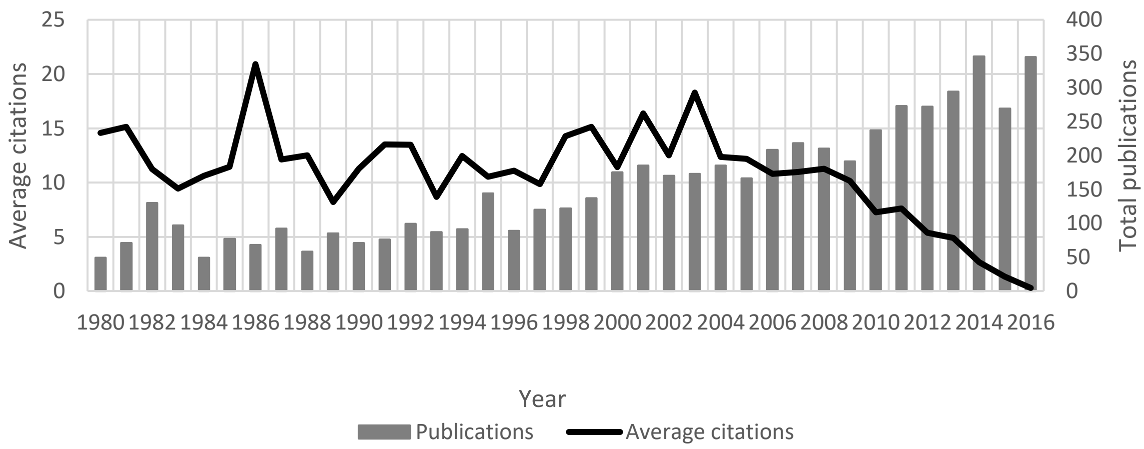


Figure 8.15: Average annual citations of SADC water research compared to the total number of articles published (1980–2016)

Source: Clarivate Analytics™ Web of Science™

Table 8.4: Citations of SADC water research publications (1980–2000)

		Citations per year																						
Year	**Total publica-tions**	**80**	**81**	**82**	**83**	**84**	**85**	**86**	**87**	**88**	**89**	**90**	**91**	**92**	**93**	**94**	**95**	**96**	**97**	**98**	**99**	**00**	**Total number of citations (1980–2016)**	**Average number of citations (1980–2016)**
1980	49	6	38	27	22	19	16	30	21	18	18	13	25	24	15	15	20	20	27	18	20	14	714	14,57
1981	71	0	8	39	54	42	56	41	38	25	19	24	29	33	23	18	23	22	22	37	32	19	1074	15,13
1982	130		0	21	44	27	38	35	39	16	24	20	28	17	22	24	19	32	32	26	28	35	1461	11,24
1983	97			0	7	48	64	44	29	34	27	23	34	36	28	31	25	34	36	28	33	23	916	9,44
1984	49				0	18	18	34	38	16	15	17	23	18	11	16	16	18	23	17	18	11	521	10,63
1985	77					0	4	50	51	49	38	23	37	35	30	35	22	34	37	45	39	33	882	11,45
1986	68							15	48	45	42	47	59	43	33	67	53	58	57	61	72	48	1 422	20,91
1987	92								8	50	37	33	28	48	34	41	22	40	38	33	42	39	1 115	12,12
1988	58									6	36	30	37	30	23	34	33	37	34	31	32	25	725	12,50
1989	85										13	40	41	44	35	35	31	34	26	24	33	23	698	8,21
1990	71											3	40	19	27	27	24	27	32	20	37	29	801	11,28
1991	76												8	53	51	54	42	49	45	36	50	56	1 027	13,51
1992	99													3	68	60	53	57	47	66	64	58	1 335	13,48
1993	87														24	36	30	26	25	29	22	26	755	8,68
1994	91															4	35	45	52	57	72	64	1 133	12,45
1995	144																7	86	65	69	85	70	1 516	10,53
1996	89																	18	40	51	57	42	988	11,10
1997	120																		10	51	45	52	1 182	9,85
1998	122																			4	51	46	1 742	14,28
1999	137																				40	45	2 072	15,12
2000	175																					24	1 997	11,41
TOTAL	**1 987**	**6**	**46**	**87**	**127**	**154**	**196**	**249**	**272**	**259**	**269**	**273**	**389**	**403**	**424**	**497**	**455**	**637**	**648**	**703**	**872**	**782**	**24 076**	**12,12**

Note: This table should be read in conjunction with Table 8.5

Source: Clarivate Analytics™ Web of Science™

Table 8.5: Citations of SADC water research publications (2001–2016)

Year	Total publi-cations	Citations per year																Total number of citations (2001–2016)	Average number of citations (2001–2016)
		01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16		
2001	185	17	90	104	131	123	144	214	202	224	226	233	258	254	246	267	296	3 029	16,37
2002	170		7	63	101	125	122	171	171	160	154	184	155	175	172	175	190	2 125	12,50
2003	173			20	81	133	200	212	234	265	266	263	280	311	288	333	277	3 163	18,28
2004	185				14	92	158	193	193	195	191	208	187	241	186	213	214	2 285	12,35
2005	166					16	107	149	164	192	192	185	188	203	211	193	224	2 024	12,19
2006	208						28	118	194	201	230	249	221	273	240	214	281	2 249	10,81
2007	218							37	155	224	236	271	258	299	299	297	316	2 392	10,97
2008	210								44	159	244	277	299	333	328	337	345	2 366	11,27
2009	191									56	158	231	278	281	323	321	292	1 940	10,16
2010	237										70	186	208	291	294	344	326	1 719	7,25
2011	273											62	231	371	458	453	506	2 081	7,62
2012	272												54	212	353	395	449	1 463	5,38
2013	294													82	318	508	531	1 439	4,89
2014	346														79	342	494	915	2,64
2015	269															62	296	358	1,33
2016	345																99	99	0,29
TOTAL	**3742**	**17**	**97**	**187**	**327**	**489**	**759**	**1 094**	**1 357**	**1 676**	**1 967**	**2 349**	**2 617**	**3 326**	**3 795**	**4 454**	**5 136**	**29 647**	**7,92**

Note: This table should be read in conjunction with Table 8.4

Source: Clarivate Analytics™ Web of Science™

As indicated earlier, citation values need to be corrected for field differences. The ‘mean normalised citation score’ (MNCS) is such a normalised indicator. An analysis of the MNCS-values for SADC water research publications is presented in Table 8.6, with the annual distribution of the MNCS presented in Figure 8.16. A MNCS-value of 1 means that the citation impact of a specific set of publications (e.g. SADC publications) are generating citation rates than other equal to the world average for publications in that field, The MNCS values for water research publications from the SADC region were well above 1 in the early 1980s. Since then, these values steadily declined. As a result, even though the volume water research articles produced by authors in the SADC region has increased steadily over the years, the citation impact has declined especially since the turn of the century. This, unfortunately, means that the increased production has not occurred with a commensurate increase in visibility.

Table 8.6: Mean normalised citation scores (MNCS) of SADC water research publications (1980–2016)

Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Number of publications	49	57	64	64	43	65	62	89	58	72	69	70	94	78	76	110	74	92	85	127
MNCS	1,1188	1,6044	1,1336	1,5067	1,2877	1,2006	1,1920	0,8235	0,9521	0,9510	0,6577	1,0198	0,9316	0,7048	0,6825	0,8027	0,8448	0,5510	0,5152	0,6989

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Number of publications	106	125	119	169	183	157	170	198	195	185	193	237	250	253	327	248	334
MNCS	0,7332	0,7447	0,5816	0,5406	0,5349	0,6328	0,6434	0,6077	0,6438	0,6197	0,5914	0,6514	0,5735	0,7923	0,6078	0,5956	0,5974

Note: The number of publications in Table 8.6 are fewer than the number of publications in Table 8.4 and Table 8.5, as the calculation of the MNCS only consider the number of articles, letters and reviews, whereas Table 8.4 and Table 8.5 present all document types.

Source: Clarivate Analytics™ Web of Science™ and calculated by the CREST

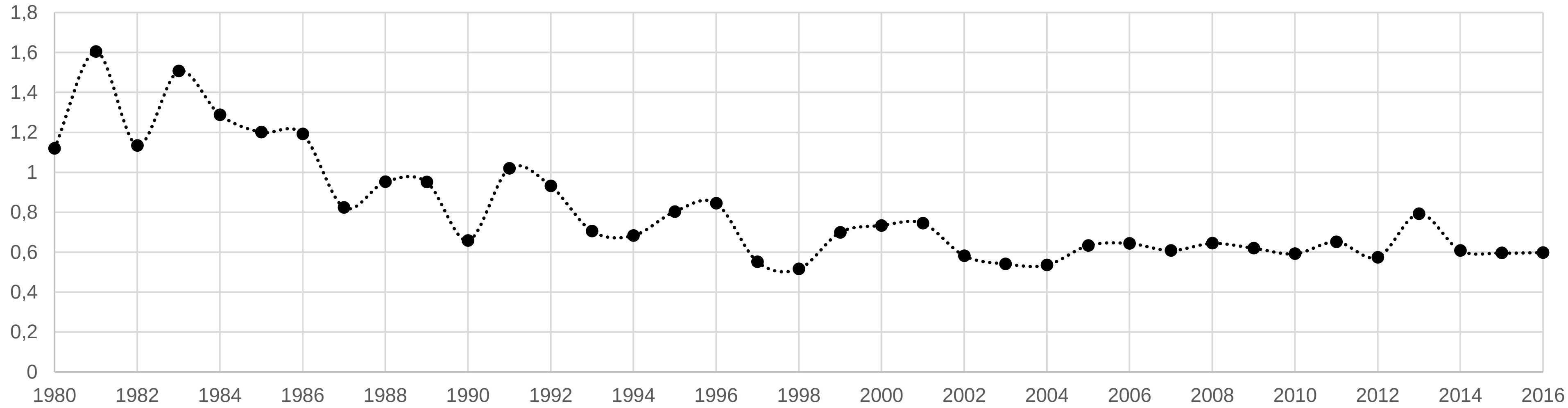


Figure 8.16: Distribution of the MNCS of SADC water research (1980–2016)

Source: Clarivate Analytics™ Web of Science™

Continuing with the analysis of the citation trends of water research from the SADC region, the annual average citation rate provides insight into the citation rates over the lifespan of an article. In this regard, there have been a couple of articles, which had been cited continuously since their publication, with the number of articles with an annual average citation rate of more than five per year presented in Table 8.7. From Table 8.7, it is further evident that 82 publications have received an annual average citation rate of between 5 and 20 citations per year, and eight publications with more than 20 citations per year.

Table 8.7: Water research articles in SADC countries with an average of more than five citations per year (1980–2016)

	Annual average citation between:			
	5 and 10 per year	11 and 15 per year	16 and 20 per year	20+ per year
Number of publications	70	8	4	8

Source: Calculated from data obtained from Clarivate Analytics™ Web of Science™

When further analysing the publication year of these articles, it is evident that many of the articles that had a high average annual citation rate, were published since the late 1990s, as indicated in Figure 8.17. From Figure 8.17, it is evident that the eight articles that had received more than 20 citations per year since their publication, were dispersed over the years, with two published before 2000, and the six published after the turn of the century. These articles published quite a few years ago, have consistently been of significance to the scientific community, even after quite a number of years. One article in particular, by Bosch and Hewlett (1982) has been cited consistently since its publication in 1982, with an average annual citation rate of 28,89. Considering that most articles have been cited on average 4,1 times over their entire lifespan, this is significant.

More recently, three articles have been cited often by scholars and published after 2010, namely by Hrachowitz, Savenije, Blöschl, McDonnell, Sivapalan, Pomeroy, et al. (2013), McVicar, Roderick, Donohue, Li, Van Niel, Thomas, et al. (2012) and Montanari Young, Savenije, Hughes, Wagener, Ren, et al. (2013), which averaged 46, 4,60 and 39,5 citation per year since their publication in 2013 and 2012 respectively. In a relatively short period, these articles have drawn the attention of various water researchers, and it would be interesting to follow these articles in future to see for how long they stay highly relevant.

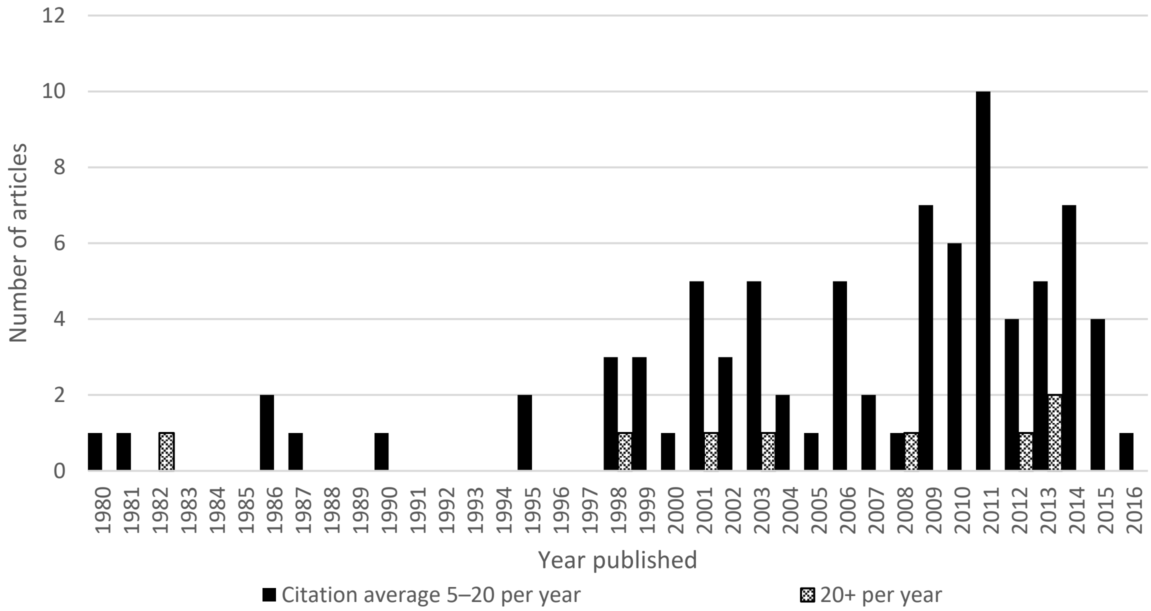


Figure 8.17: Distribution of water research articles from the SADC region with a high average number of citations per year (1980–2016)

Source: Calculated from data obtained from Clarivate Analytics™ Web of Science™

From Figure 8.17 it is further evident that 14 of the 82 articles, which had received between 5 and 20 citations per year since their publication, were published before 2000, with the bulk being published since the year 2000. There are further 31 publications, which had been published since 2010, which received between 5 and 20 citations annually. It will however be interesting to follow these articles, in order to ascertain whether they can maintain the high citation rate over time, as in the case of the articles published before 2000.

It is therefore evident that there are a very small number of publications that have been cited consistently over the years, with an increase in such publications since the turn of the century, when the number of publications in the region has also increased. Particularly between 2009 and 2011, a number of publications were published and cited regularly.

Our focus can now turn towards the journals in which researchers from the region have published articles, with the following section analysing the journal publication trends of water research in the SADC region between 1980 and 2016.

8.5 Distribution of SADC water research articles by journal

Within the science community, it is important for researchers to publish their work in peer-reviewed journals. Even though the shortcomings of peer-review are well documented (Weller, 2001), and the challenges relating to the rise of predatory journals[20] are evident (Bohannon, 2013; Gasparyan, Yessirkepov, Diyanova & Kitas, 2015; Mouton & Valentine, 2017; Švab & Makivić, 2015), the publishing of articles in accredited peer-reviewed journals is still regarded as an integral part of the science process. Moreover, publication and citation data of articles that are published in well-established journals and which adhere to principles of rigorous peer review, are captured in citation databases. These citation databases present journal citation reports (JCR), and in the case of the Clarivate Analytics™ InCites™ JCR, citation data from approximately 12 000 journals and conference proceedings from over 3 000 publishers are analysed and presented in an online module (Clarivate Analytics, 2017).

In terms of this study, citation data from water research publications between 1980 and 2016 were analysed to identify the top 10 journals (by total number of publications) in which researchers from the SADC region had published. The results are presented in Table 8.8.

From Table 8.8, it is evident that water researchers in the SADC region have published almost a third of all publications (31,66%) in the South African journal *Water SA* (ranked between 57th and 69th between 2012 and 2016). Other journals in the top three include *Water Science and Technology* (comprising 11,85% of publications and ranked 44th to 61st amongst journals between 2012 and 2016) and *Physics and Chemistry of the Earth* (comprising 9,48% of publications and ranked between 38th and 55th amongst journals between 2012 and 2016). The top three journals are followed by some of the top-ranked foreign journals in the water research field, such as *Water Research*, *Desalination* and *Journal of Hydrology,* consistently ranked in the top 10 global journals since 2012. *Water Research* was ranked 1st during this time. These three journals accounted for almost 7% of SADC water research publications between 1980 and 2016.

Other top journals are *Agricultural Water Management* (ranked between 10th and 18th between 2012 and 2016), *Hydrological Sciences Journal (Journal Des Sciences Hydrologiques),* ranked between 16th and 43rd between 2012 and 2016, the *IAHS Publication,* and finally, the *Water Air and Soil Pollution* (ranked between 27th and 39th between 2012 and 2016). The final four journals account for 5,76% of publications.

[20] Predatory journals often lack active editorial boards, prioritise financial profit and lack adequate peer-review procedures (Clark & Thompson, 2017; Pickler et al., 2015).

Table 8.8: Top 10 journals of water research publications in SADC (1980–2016)

Rank	Journal titles	Number of publications	% of publications	Journal rank				
				2016	2015	2014	2013	2012
1	WATER SA	1 814	31,66%	66/88	62/85	69/83	61/81	57/80
2	WATER SCIENCE AND TECHNOLOGY	679	11,85%	61/88	54/85	52/83	44/81	44/80
3	PHYSICS AND CHEMISTRY OF THE EARTH	543	9,48%	55/88	47/85	38/83	38/81	47/80
4	WATER RESEARCH	152	2,65%	1/88	1/85	1/83	1/81	1/80
5	JOURNAL OF HYDROLOGY	134	2,34%	6/88	6/85	7/83	10/81	5/80
6	DESALINATION	112	1,95%	2/88	2/85	2/83	2/81	4/80
7	AGRICULTURAL WATER MANAGEMENT	101	1,76%	14/88	10/85	16/83	18/81	15/80
8	HYDROLOGICAL SCIENCES JOURNAL (JOURNAL DES SCIENCES HYDROLOGIQUES)	83	1,45%	24/88	16/85	36/83	39/81	43/80
9	WATER AIR AND SOIL POLLUTION	76	1,33%	39/88	35/85	35/83	31/81	27/80
10	IAHS PUBLICATION	70	1,22%	Null	Null	Null	Null	Null
	Other journals	1 965	34,30%					

Note: Null value in the Journal Rank: the Journal Citation Report was not available

Source: Clarivate Analytics™ Web of Science™ and InCites™ Journal Citation Reports®

It is evident that, given the large volume of water research emanating from South African institutions, water researchers in the SADC region have predominantly published in the local journal *Water SA*, at just over 30% of all publications. The top three journals, which account for 53% of all publications, rank within the 3rd quartile of journals in the same research category. Moreover, only about 7% of water research has been published in top journals that are ranked in the 1st quartile, meaning that these journals perform better than 75% of other water research journals. These journals are *Water Research*, *Desalination* and *Journal of Hydrology.*

When further analysing the journal publishing trends over time, as presented in Figure 8.18 and Figure 8.19, for clarity, the top 10 journals are presented in two separate figures. Here it becomes evident that there have been some instances where publications in specific journals have increased over time, such as in the case of *Water SA* (Figure 8.18). Publication in other journals has remained constant, as in the case of the journals *Water Research* and *Journal of Hydrology*.

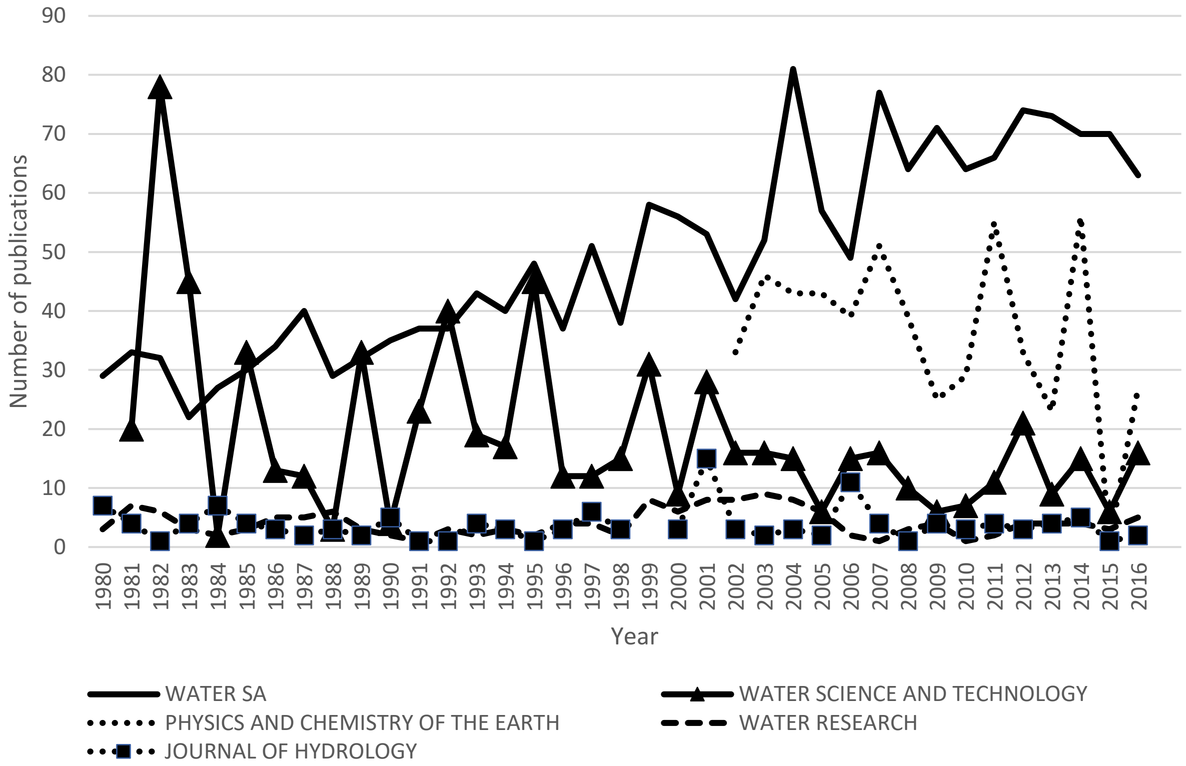


Figure 8.18: Annual distribution of SADC water research publications between 1980 and 2016: Top 1–5 journals

Source: Clarivate Analytics™ Web of Science™

The most evident trend however, is the sporadic increases in the number of publications some journals have experienced over time. Journals such as *Physics and Chemistry of the Earth* (in 2007, 2011, 2014 and 2016), *Water Science and Technology* (several years between 1982 and 2016), *Agricultural Water Management* (1990 and 2011), the *IAHS Publication* (2002, 2006 and 2011) and, to an extent, *Water SA* (in 2004 and 2007).

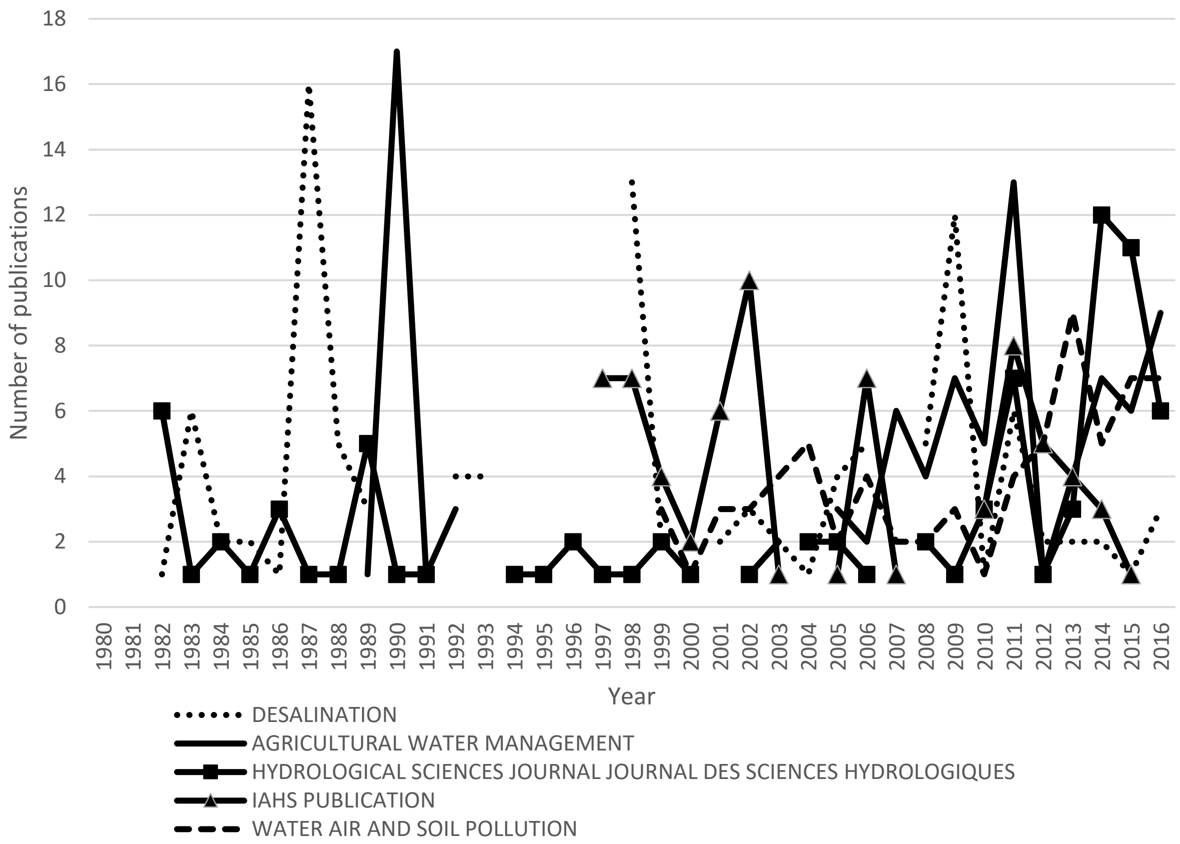


Figure 8.19: Annual distribution of SADC water research publications between 1980 and 2016:
Top 6–10 journals

Source: Clarivate Analytics™ Web of Science™

A further analysis of these sporadic increases suggests that in some cases, conferences took place, with associated publications following the conference. The effect of such a conference and the subsequent publication of articles in a specific journal should not be underestimated, as is evident in Table 8.9 where, for example in the late 1990s, 87% of articles published in the *IAHS Publication* and 68% of the articles published in the journal *Water Science and Technology* resulted from single conferences. In other cases, the percentage of articles was between 20% to 47%, and in the case of the *IAHS Publication* in 2011, all contributions from the conference were published as chapters in a book series.

These high percentages of publications in specific journals could have resulted from the theme of the conferences being in line with specific fields published by a journal, therefore naturally attracting the proceedings of the conference. In other cases, a conference organiser or sponsor might have had an agreement with a specific journal and therefore contributions from the conference were published in a journal following the conference.

Table 8.9: Number of water research publications resulting from specific conferences in the SADC region

Journal	Number of publications resulting from specific conferences	% of journal publications in year
WaterSA:	26 articles resulting from the Biennial Conference of the Water Institute of South Africa. Location: Cape Town, South Africa. Date: 02–06 May 2004. **Publication year: 2004**	31%
	14 articles published from the International Symposium on the Nutritional Value and Water Use of Indigenous Crops for Improved Livelihoods. Location: Pretoria, South Africa. Date: 19–20 Sep 2006. **Publication year: 2015**	20%
	15 articles published from the Water Institute of Southern Africa (WISA) Biennial Conference. Location: Mbombela, South Africa.. Date: 25–29 May 2014. **Publication year: 2015**	21%
Water Science and Technology	21 articles published from the 7th International Symposium on River Basin Management for Sustainable Development. Location: Kruger National Park, South Africa. Date: 15–17 May 1995. **Publication year: 1995**	47%
	21 articles published from the International Specialised Conference on Chemical Process Industries and Environmental Management. Location: Cape Town, South Africa. Date: 08–10 Sep 1997. **Publication year: 1999**	68%
	17 articles published from the 1st international specialised conference on membrane technology in wastewater management Location: Cape Town, South Africa. Date: 02–05 Mar 1992. **Publication year: 1992**	43%
Agricultural Water Management	8 articles published from the symposium on the irrigation of sugar cane and associated crops. Location: Reduit, Mauritius. Date: 18–22 APR 1988. **Publication year: 1990**	47%
IAHS Publication	8 publications resulting from 25th General Assembly of the International Union of Geodesy and Geophysics. Location: Melbourne, Australia. Date:28 JUN–07 JUL 2011. Risk in water resources management. Book Series: IAHS Publication Volume: 347 pages: 127 **Publication year: 2011**	100%
	6 publications resulting from the Conference: International Conference on Water Resources Variability in Africa During the 20th-Century. Location: Abidjan, Cote Ivoire. Date: 16–19 Nov 1998. **Publication year 1998**	87%

Source: Clarivate Analytics™ Web of Science™

In the case of the journal *Physics and Chemistry of the Earth*, publication of water research started in the early 2000s. In recent years, water research in the journal *Physics and Chemistry of the Earth* has been more sporadic, with 56 publications in 2014, followed by 0 publications in 2015, and 27 articles in 2016 (see Figure 8.18). It is however known that the journal *Physics and Chemistry of the Earth* has a close association with the annual WaterNet/WARFSA/GWP-SA symposium, the largest water research symposium in the SADC region, which started in 2000. Annually, the conference publishes articles in a special issue of the journal *Physics and Chemistry of the Earth*. This relationship will be discussed in more detail in Chapter 10 where the publications of countries, which exclude South Africa, will be presented in detail, and further in Chapter 11, where knowledge production resulting from the Water Research Fund of South Africa (WARFSA) will be discussed in more detail.

Having presented the journal distribution of water research from the SADC region, the support for the research can be investigated. In Chapter 6, the institutional landscape of the SADC water sector was presented, highlighting the programmes and network initiatives (6.3), the international organisations (6.4), research and innovations units such as the Water Research Commission (WRC) in South Africa (6.5), and other societies, associations and academies (6.6). All these institutions play an important role in supporting water research in the region. The following sections provide some insight into the distribution of such support, as it translates into publication of water research.

8.6 Support for water research in all SADC countries: An analysis of funding acknowledgements

With water research being a multi- and interdisciplinary research field, and many programmes, initiatives and institutions supporting water research in the region (as evident from Chapter 6), it is a challenge to identify the extent to which such agencies provide support for water research accurately. One source that could provide some insight into which organisations and to which extent they support research is the acknowledgements researchers give in the publication. There are however limitations, in that the Web of Science (WoS) has only been capturing funding acknowledgements actively since August 2008. Researchers further often neglect to acknowledge funding support in their articles, unless it is specifically requested by the funding agency. Moreover, when institutional information is captured in the WoS citation database, it is often found that different spellings exist for the same institution, which results in inaccurate totals presented in the reporting. One should acknowledge that other databases exist from where funding support could be extrapolated, such as the NRF and WRC; however, this is data for South Africa only and similar datasets are not readily available in other SADC countries. Given these limitations, it was decided to continue using the WoS citation dataset, in order to present some regional perspective.

An analysis of the 5 729 water research articles published in the SADC region between 1980 and 2016 revealed that acknowledgement data were not available for 78,86% of the publications. The available funding agency data were further limited to after 2007. For this reason, funding agency data were restricted to water research publications in the SADC region between 2008 and 2016, which resulted in the analysis of 2 437 publications. For these publications, 2 323 funding agency records were extracted and categorised according to the following categories:

- Type of funding agency:
  a. research funding agency, such as the South African National Research Foundation, Water Research Commission, or Swedish Sida;

b. university or research institute, typically based at a university;
c. a government department;
d. private industry;
e. other – a small percentage of institutions could not be categorised, and are therefore indicated as ‘other’, as insufficient information are available on the records.

- Geographical location:

a. Local within the SADC region: research funding agencies, universities/research institutes, government ministries and departments and private industry. In addition, in order to provide a better indication of South African support versus the rest of the SADC region, data for the local research funding agencies and university/research institutes were further divided indicating the portion of South African agencies and universities/research institutions versus the rest of the SADC.

b. International research funding agencies, universities/research institutes and government ministries and departments.

Results of the categorisation are presented in Table 8.10 and Figure 8.20.

Table 8.10: SADC water research funding institutions (2008–2016)

Type of funding organisation	Geographical	Count	% of total acknowledgements
Research funding agency	Local	798	34,4%
Research funding agency	*South African*	751 (of 2 323)	32,3%
Research funding agency	*Rest of SADC countries*	47 (of 2 323)	2,0%
Research funding agency	International	543	23,4%
University/research institute	Local	355	15,3%
University/Research institute	*South African*	233 (of 2323)	10,0%
University/Research institute	*Rest of SADC countries*	122 (of 2323)	5,3%
University/Research institute	International	147	6,3%
Government	Local	162	7,0%
Government	International	114	4,9%
Private industry	Local	95	4,1%
Private industry	International	55	2,4%
Other		54	2,3%
TOTAL		**2323**	**100%**

Note: Funding agency records were limited to between 2008 and 2016, as Clarivate Analytics™ Web of Science™ only started capturing such data actively in 2008.

Source: Clarivate Analytics™ Web of Science™

From Table 8.10, it is encouraging to note that for the period 2008 to 2016, local research funding mechanisms were acknowledged 60% of all water research funding agencies in the SADC region, while international funding mechanisms acknowledged 37%. One should however interpret this finding with caution, given the dominance of South African water research output in the SADC region as will become evident later in this section. A further analysis of these findings is also presented in the following chapters.

Keeping this in mind, **local funding mechanisms** are divided into 34,4% support through research funding agencies, such as the WRC and national research foundations in the SADC countries, 15,3% through universities and research institutions in the SADC countries, 7% through government institutions, and 4,1% private industry in the SADC countries (Figure 8.20). On the other hand, the **international funding mechanisms** are divided into 23,4% international research funding agencies such as USAID and the Swiss national Science Foundation, 6,3% international universities and research institutions, 4,9% international governments and 2,4% private industry. It is evident that between the local and international funding agencies, the ratios between research funding agencies, universities/research institutions, governments and private industry are more or less the same.

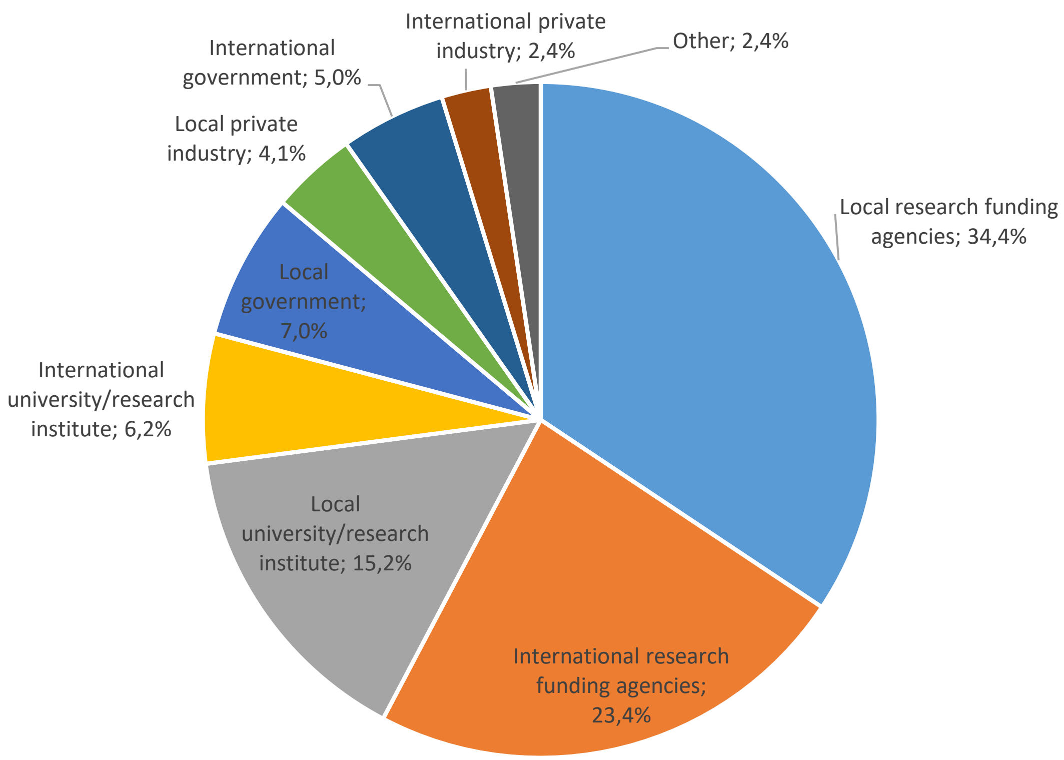


Figure 8.20: SADC vs. International funding mechanisms for SADC water research (2008–2016)

Source: Clarivate Analytics™ Web of Science™

A detailed analysis of the data however indicates that South African research funding agencies have been acknowledged in 32,3% as funding agency in water research in the SADC region. A brief calculation indicates that the South African Water Research Commission (WRC) and the South African National Research Foundation (NRF) accounted for almost two thirds of local research funding agency acknowledgements in the SADC region.

The same is true for local universities and research institutions, where South African universities and research institutions have supported 10% of all research in the region, and other universities and research institutions from the other SADC countries, 5,3% of all research. This can be attributed to the large number of institutions in South Africa, with many other SADC countries often having very few universities and research institutions conducting water research.

In terms of private industry contributions towards water research in the SADC region, it is evident that 4,1% were acknowledged as local industry, and 2,4% from international industry. As these figures are dependent on researchers acknowledging funding agencies in scientific articles when they are submitted to scientific journals, one would suspect that the contribution from private industry could actually be higher, as their research would translate into patents with an economic potential, rather than peer-reviewed articles.

8.7 Summary and conclusion

In this chapter, various aspects of water research in the SADC region were analysed and presented. These aspects included an overview of water research produced in the region between 1980 and 2016, where it became evident that a steady increase in water research has occurred, and that 81% of all water research produced during this period, resulted from researchers from South African universities and research institutions. In the SADC region, countries such as Zimbabwe, Tanzania, Botswana and Malawi have contributed towards water research in region, albeit it at a much smaller scale. There has however been a faster increase in water research publications from SADC countries beyond South Africa since the turn of the century.

As can be expected, even though many researchers have contributed towards water research in the region, there are a few researchers who have contributed many publications (again, mostly from South African universities), with many of their research further obtaining the bulk of citations. Moreover, it is evident that some water research networks exist in the SADC region, often focussed on these prolific researchers. Where research networks are found in other SADC countries than South Africa, it is often in collaboration with researchers from the Netherlands, who are supporting the WaterNet programme and annual WaterNet/WARFSA/GWP-SA symposium. This conclusion will become more significant when an analysis of the water research in SADC countries where South Africa is excluded, is reported in Chapter 10, and when the knowledge produced from the WARFSA programme is presented in Chapter 11.

Over the years, SADC water researchers have increasingly co-authored publications with other researchers, with sharp increases in publications with four and more authors in recent years, comprising 46% of all publications. At the same time, single-authored publications are the least, comprising less than 10% of publications. Where publications were co-authored, these were often with researchers from the same SADC countries, followed by researchers beyond SADC. Moreover, there are only a few SADC researchers who have co-authored articles significantly with other researchers from the SADC region, as in the case of Namibia, Zimbabwe, Botswana, Malawi and Swaziland. South African researchers, from where the bulk of water research in the region originates, tend to co-author mostly with researchers from South Africa, and then beyond the region followed by other SADC researchers.

In terms of the citing of articles, 24% of water research articles in the SADC region published between 1980 and 2016, had never been cited, with most publications (52%) receiving between 1 and 10 citations at an average citation rate of 4,11 cites per article. There are however 40 articles, which account for less than 1% of all water research in the SADC region, which have been cited over 8 600 times at an average citation rate of 215,25 per article, accounting for 16% of all citations.

Based on the calculation of the mean normalised citation score (MNCS) for SADC water research publications, it is evident that even though the volume water research articles produced by authors in the SADC region has increased steadily over the years, the citation impact has declined especially since the turn of the century. This, unfortunately, means that the increased production has not occurred with a commensurate increase in visibility.

Water researchers in the SADC region have published most of their papers in *Water SA*, a journal of the South African WRC. *Water SA* comprises 32% of all publications, with other globally ranked journals accounting for 7% of all publications. Water SA was ranked 76th in the journals in the subject category “Water resources” of the Journal Citation Reports of the ISI which placed it in the lowest quartile (Q4). The fact that such a large proportion of SADC papers appeared in a low-ranked journal would explain the low global visibility of papers produced by SADC-authors.

The role of publications resulting from conferences and symposia should further not be underestimated, as is evident in the sporadic annual increases in some journals over time. It is known that *Physics and Chemistry of the Earth*, which published almost 10% of all water research in the region in the period 1980–2016, had a close association with the annual WaterNet/WARFSA/GWP-SA symposium. Once again, this relationship was assessed and is discussed in more detail in Chapter 10 when publications from SADC countries excluding South Africa will be assessed, and in Chapter 11 where knowledge that was produced from the WARFSA programme will be analysed.

Finally, it was established that 60% of water research in the SADC region was funded by local funding mechanisms, with the South African research funding agencies supporting 32% of all research in the region and South African universities and research institutions supporting 10% of all research. International funding mechanisms have contributed to a lesser degree in the region. It will however be interesting to determine the extent of support these international funding mechanisms in other SADC countries beyond South Africa, which will be discussed in more detail in Chapter 10.

Given the large number of water research from South African institutions when compared to other SADC countries, the following two chapters will report on an analysis of water research publications from South Africa and SADC countries excluding South Africa (SADC-ExSA countries). In each chapter, the research output, authorship trends, citation analysis and support for the research will be discussed in more detail.

Chapter 9

PUBLICATIONS IN THE SOUTH AFRICAN WATER SECTOR

9.1 Introduction

Water-related research is conducted at many of the universities and research institutions in South Africa. Moreover, because water-related research is regarded as an interdisciplinary research field, researchers are often based in different faculties at these universities, which results in the formation of water institutes at the institutions. Examples are the Water Research Group[21] and the newly established Future Water[22] at UCT, the Water Institute at SU,[23] the Water Institute at UP,[24] the Centre for Water Resources Research at UKZN,[25] the Institute for Groundwater Studies at UFS[26] and the Institute for Water Studies at UWC.[27] At research institutions, such as the CSIR, water research units have also been established focussing on various aspects of research in the water sector.[28] As evident from the previous chapter, these research groups often form around some of the most prolific researchers in the country, such as the Water Research Group at UCT with Prof. George Ekama, who has published the most water research by far in the SADC region. This phenomenon will be discussed in more detail in 9.2.1.

The aim of this chapter is to provide a bibliometric analysis of water research emanating from South African universities and research institutions between 1980 and 2016. By making use of bibliometric data analysis techniques, water research output for the period was analysed to establish authorship trends in the sector. In addition, co-authorship trends from water research in the South African water sector were determined. This chapter will further report on an analysis of citations from water research, and an analysis of publication records to identify the main funders who support water research in South Africa.

At this stage, it should be acknowledged that various bibliometric studies have been undertaken by South African water researchers, as discussed in detail in 3.2.2. These studies and publications include the *Pulse study on the state of water research and development in South Africa* (Pouris, 2013) analysing bibliometric data for the period 1981–2010, and the *State of water research in South Africa* (Pouris, 2015), spanning a period between 1981 and 2014. Both studies were conducted for the WRC, with the 2013 study resulting in the publication of an article (Jacobs, Pouris et al., 2014). Further studies were undertaken by Siebrits and Winter (2013) who conducted a scientometric analysis to analyse water research paradigm shifts in

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[21] http://www.civil.uct.ac.za/water-research-group
[22] http://www.futurewater.uct.ac.za/
[23] http://water.sun.ac.za
[24] http://www.up.ac.za/water-institute
[25] http://cwrr.ukzn.ac.za/
[26] http://natagri.ufs.ac.za/content.aspx?DCode=109
[27] https://www.uwc.ac.za/Faculties/NS/Water_Studies/Pages/default.aspx
[28] http://www.csir.co.za/nre/water_resources/overview.html

South Africa, specifically in relation to the pre-and post-political reform period in the mid-1990s – a study also undertaken for the WRC. The study resulted in the publication of a research article in the *South African Journal of Science* (Siebrits, Winter & Jacobs, 2014) and an article published in the journal *Water SA* (Siebrits, Winter, Barnes et al., 2014). Finally, the WRC published a reflection on South Africa's 20-year journey in water and sanitation research. In the latter study, the WRC highlights some of the successes achieved through research and related activities, which was commissioned through the WRC (Jacobs, Du Plessis et al., 2014).

In the present study, additional elements with regard to co-authorship trends, citation analysis and funding support, and over a different period, namely between 1980 and 2016 are addressed.

9.2 Water research output from South African institutions

Our bibliometric analysis of publication and citation data of water research in the South African water sector starts by providing an overview of the number of publications per year, and the number of citations these articles have received, as presented in Figure 9.1. For detail on the methodology used to extract bibliometric data, refer to section 5.3.1.

In terms of water research output in South Africa, researchers affiliated with universities and research institutions have produced 4 666 research publications between 1980 and 2016,[29] which have been cited 45 079[30] times. As further evident from Figure 9.1, publications from specific years have been cited between 8 and 21 times per year. There were, for example, years such as 1986, some years in the early 1990s and the early 2000s, where publications had been cited more regularly. As can be expected, due to the lag that occurred in the citing of publications, recent articles have not been cited as often. The citation of these articles is discussed in more detail in 9.3. In terms of the annual number of publications, significant increases were recorded between 1996 and 2001 and again between 2009 and 2014, with more than 260 articles published in 2016 (Figure 9.1). In a South African context, this is significant, but one needs to compare such observations with other indicators, such as the share of African and global water research.

[29] In extracting water research articles from the Clarivate Analytics™ Web of Science™ Core collection database, "ALL DOCUMENTS" and "ALL DOCUMENT TYPES" were selected.
[30] Includes self-citations.

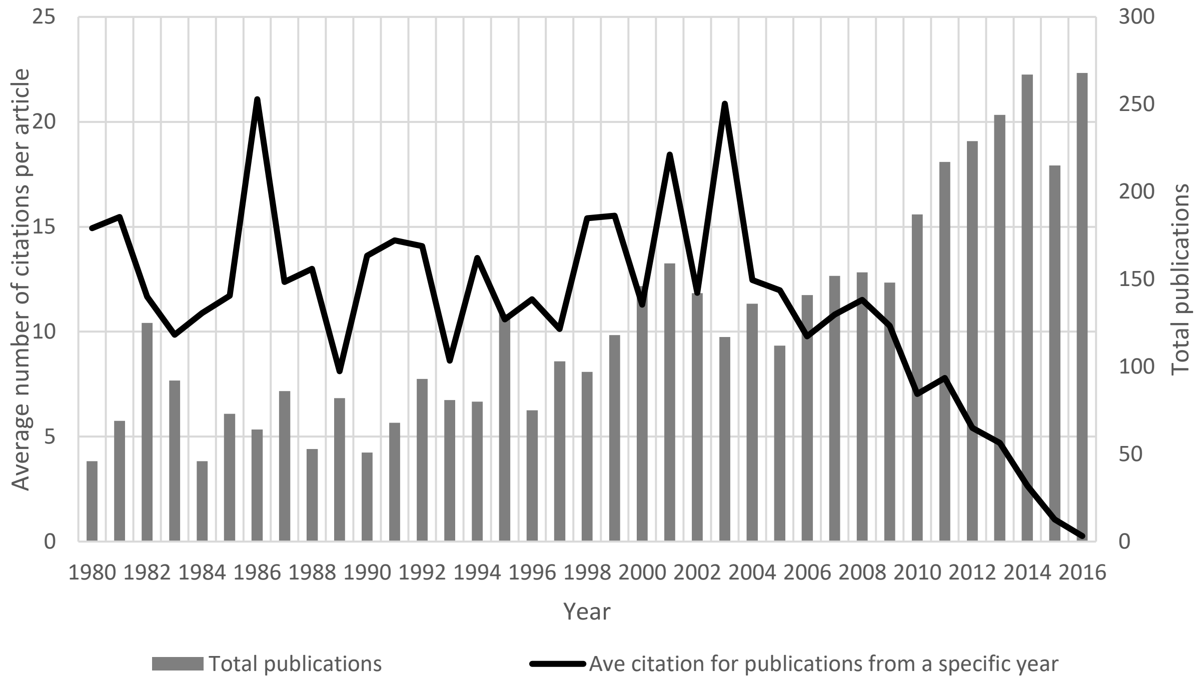


Figure 9.1: South African water research output (1980–2016)

Source: Clarivate Analytics™ Web of Science™

When compared with other indicators such as the share of African research and the world share of water research, the South African share of African water research publications has steadily declined from 84% in 1982 to 24% in 2016 (Figure 9.2). This share of African water research is still significant by any standard.

In terms of world share, South Africa produced almost 5% of water research publications in 1982, after which it declined to less than 1% in 1990. Subsequently, the world share of South African water research has remained steady between 1,71% in 1999 and 1,11% in 2015. It is thus evident that globally, South Africa has continued to contribute consistently towards water research output, and that there was an increase in water research from other African countries. These findings are in line with other studies, such as by Wambu and Ho (2016), who concluded that there has been significant increases in research output from African countries.

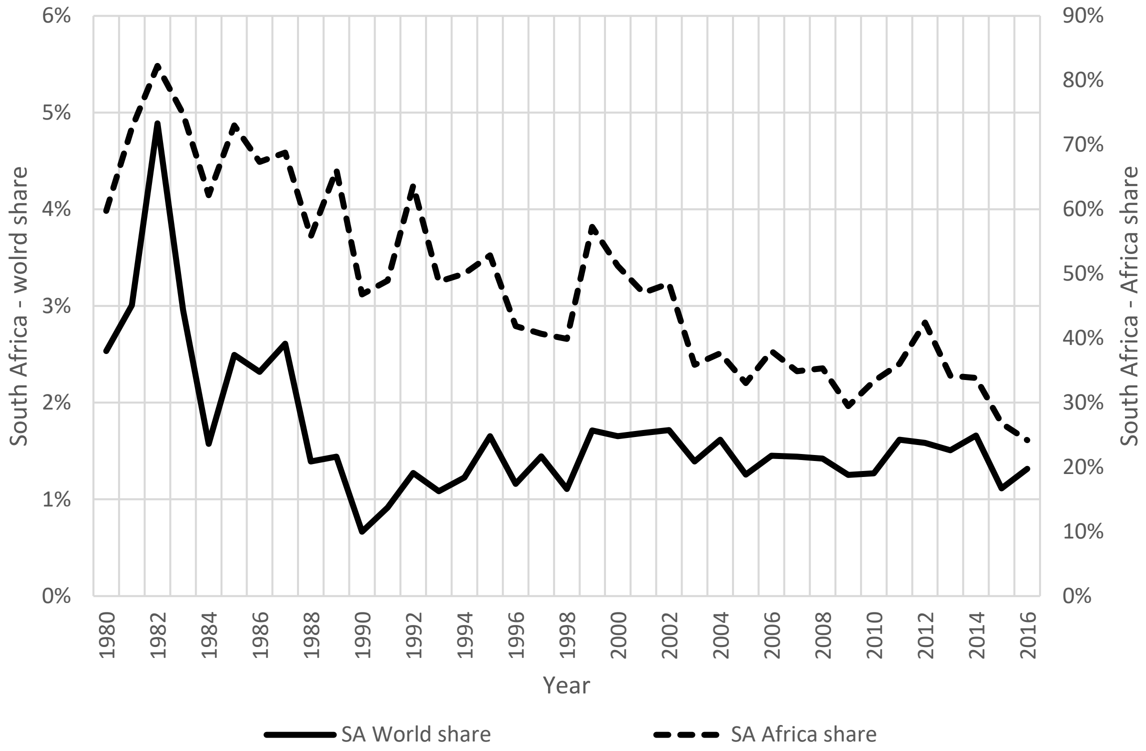


Figure 9.2: South African share of Africa and world water research publications (1980–2016)

Source: Clarivate Analytics™ Web of Science™

It is evident that water research in South Africa has contributed significantly to water research on the continent over the years. As far as the focus areas of the research are concerned an analysis of the co-occurrence of KeyWord Plus words were undertaken, to identify underlying research focus areas. The data analysis was undertaken making use of VOSViewer® software. In total, 5 306 keywords were identified and, after setting the minimum occurrence of keywords to a threshold of five, 542 keywords were identified. The results of the keyword map representing the density visualisation analysis, are presented in Figure 9.3. Here, more prominent keywords are presented as clusters with warmer colours presenting clusters of greater prominence with colour contours presenting how strongly related the keyword clusters are. It is clear (Figure 9.3) that water research in South Africa in the period 1980–2016 mainly focussed on 'water' 'management' in 'South Africa', with links to 'performance', 'modelling', 'climate change' and 'catchments'. In addition, prominent clusters are evident with keywords such as 'removal' and 'heavy metals' and 'drinking water' and 'groundwater'. These findings are more or less in line with the findings by Siebrits, Winter and Jacobs (2014), who found that water research output in the period 1977 to 2006 mainly focussed on management, development, models, quality and system treatment, with two paradigm shifts evident where the focus of water research changed over time. The paradigm refers to before 1991, when the focus was on the ‘hydraulic mission’ of South Africa, with many engineering and laboratory-related research undertaken. After 1991, water research in South Africa focussed mainly on management and planning of water resources (Siebrits, Winter & Jacobs, 2014).

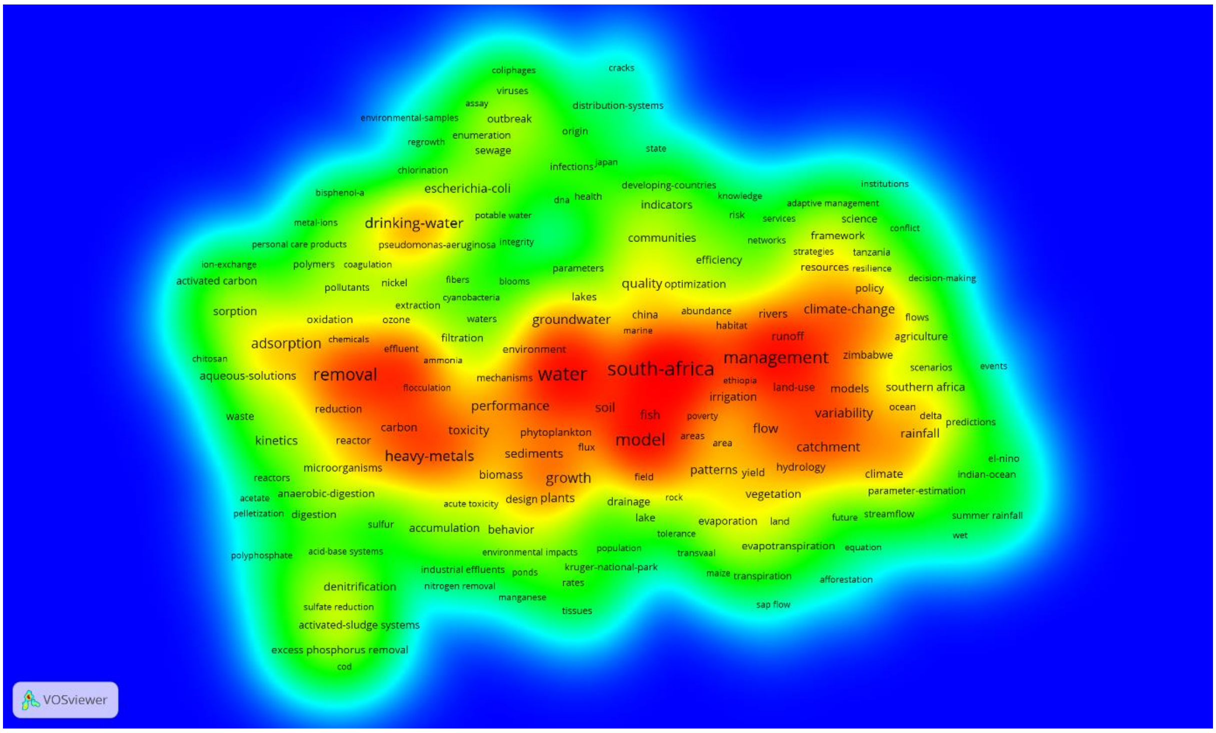


Figure 9.3: Density visualisation of KeyWord Plus words of water research in South Africa (1980–2016)

Source: Clarivate Analytics™ Web of Science™

Our focus now moves towards the authorship characteristics of water research in South Africa, with the following section discussing the authorship and co-authorship trends of water research published from South African universities and research institutions.

9.2.1 Authorship of South African water research

Previous research has highlighted ‘prolific’ researchers in the South African water sector, which included researchers such as Prof. Ekama and Prof. Wenzel at UCT (Pouris, 2013). In this study, the bibliometric analysis of publication data indicates that 6 532 researchers contributed towards the publication of the 4 666 water research publications between 1980 and 2016. Following Alfred Lotka’s observations (Lotka, 1926), who found that a few researchers produce the bulk of research in a particular field, Figure 9.4 presents the percentage of researchers who have published between one and 21 and more publications. Here it is evident that 4 397 (67,3%) authors have published one publication, and 994 (15,2%), 365 (5,6%) and 212 (3,2%) have published two, three and four publications respectively. On the other end of the scale, there are 45 researchers who have published more than 20 publications each. This is presented in Table 9.1.

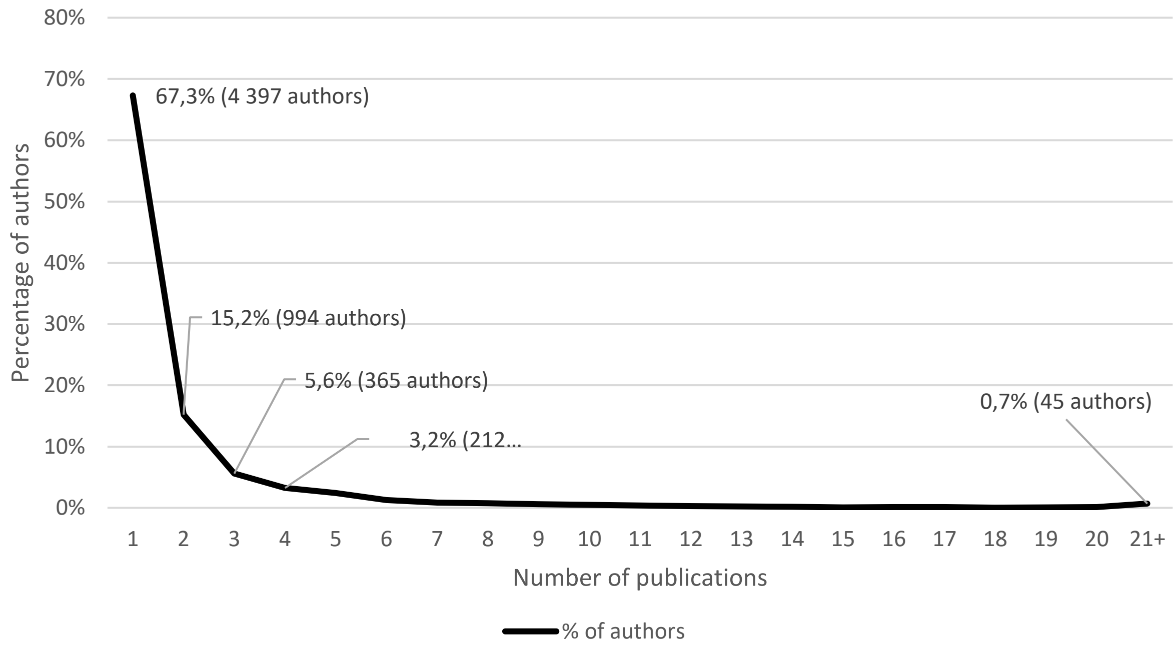


Figure 9.4: Distribution of South African water research publications by number of publications between 1980 and 2016

Source: Clarivate Analytics™ Web of Science™

As indicated in Chapter 7, water research in the SADC region is dominated by South African researchers, and for that reason, Table 9.1 does not differ much from Table 8.2. These tables list the SADC water researchers (Table 8.2) and South African water researchers (Table 9.1) who have published more than 20 water research publications, the number of publications per author (also presented as a percentage of total publications), the average citations per item and the *h*-index of the author for the published articles in this research field. In addition, the number of times articles have been cited, the number of self-citing articles (further presented as a percentage of articles), the institution and country of the researchers are listed, and if the researcher can be associated with a WARFSA publication.

From Table 9.1, it is evident that water researchers such as Prof. George Ekama and Prof. Mark Wentzel (from UCT), Prof. Denis Hughes (RU) and Prof. Chris Buckley (UKZN) have produced the largest number of publications in South Africa between 1980 and 2016. Other researchers from various universities and research institutions in South African are present amongst the water researchers who have had more than 20 publications, and include UP, UJ, SU, the CSIR, UWC, Wits, Tshwane University of Technology (TUT), UL, DUT, CPUT, UV, UNIZULU and UFS and IWMI.

A notable differences between prolific SADC water researchers in the entire SADC region Table 8.2), and water researchers contributing towards South African publications, is the absence of researchers from outside South Africa, namely:

- Prof. Mazvimavi, now ranked amongst the top 50–100 researchers;
- Prof. Innocent Nhapi (214) from Zimbabwe;
- Prof. Makurira now ranked between 150 and 200th;
- Prof. Pieter van der Zaag from the Delft University of Technology/UNESCO IHE in the Netherlands, now ranked between 300 and 350th; and
- Dr David Love, now ranked outside the top 500 South African researchers by number of publications.

This would suggest that these researchers collaborate with researchers in the SADC outside South Africa. These patterns of research collaboration are discussed in more detail in Chapter 10 (see section 10.2.2).

In terms of self-citation rates amongst the more prolific water researchers in South Africa, it is evident that there are researchers who are often well above the South African self-citation average of 4,4%.[31] Even if one considers that the average self-citation rate amongst the more prolific researchers are 8,4%, there are 18 water researchers with a self-citation rate above 8,4% and 30 researchers above the South African self-citation rate of 4,4. With studies showing that self-citations could influence the *h*-index of researchers (Bartneck & Kokkelmans, 2011; Hirsch, 2005; Zhivotovsky & Krutovsky, 2008), one would have to consider this factor when interpreting the *h*-index of researchers.

Table 9.1 presents the *h*-index of the South African water researchers who have had more than 20 publications, reflecting that there are four researchers who had an *h*-index of above 20. In the case of Prof. Ekama, with an *h*-index of 33, this would indicate that he had published 33 articles that had been cited 33 times – 33 out of his total of 155 articles. In the case of Prof. Marais, who had published less than half of Prof. Ekama's articles at 54 articles, this meant an *h*-index of 22. Refer to section 5.3.2.1 for a more detailed explanation of the *h*-index. It is thus evident that even amongst the more prolific researchers there are only a few researchers who have a significant number of publications that are cited regularly.

Finally, Table 9.1 provide an indication if the researchers could be associated with any WARFSA-related publication. Here it is evident that very few researchers of the researchers in South Africa are linked to WARFSA-related publications. This will be investigated further in Chapter 11.

[31] An updated analysis of South African water research articles based on the same query parameters for this study was done in December 2017, indicating that the average self-citation rate for water research articles in South Africa is 4,4%.

Table 9.1: Researchers who have published more than 20 water research publications in South Africa (1980–2016)

Rank	Authors	Publications	% of 6 532 publications	Average citations per item	Times cited	Self-citations	Self-citations as % of articles	*h*-index	Organisation	Country	WARFSA Publication association
1	EKAMA GA	155	3,32%	26,48	4105	758	18,5%	33	UCT	South Africa	No
2	WENTZEL MC	112	2,40%	30,61	3428	472	13,8%	29	UCT	South Africa	No
3	HUGHES DA	103	2,21%	15,02	1547	292	18,9%	21	RU	South Africa	No
4	BUCKLEY CA	103	2,21%	11,57	1 192	28	2,3%	17	UKZN	South Africa	No
5	MAMBA BB	68	1,46%	6,31	429	40	9,3%	12	UJ	South Africa	No
6	GRABOW WOK	67	1,44%	16,03	1 074	57	5,3%	18	UP	South Africa	No
7	CLOETE TE	64	1,37%	10,83	693	40	5,8%	15	SU and UP	South Africa	Yes
8	HAARHOFF J	62	1,33%	7,47	463	40	8,6%	13	UJ	South Africa	No
9	SCHOONBEE HJ	54	1,16%	7,15	386	107	27,7%	11	UL	South Africa	No
10	MARAIS GV	54	1,16%	36,06	1 947	65	3,3%	22	UCT	South Africa	No
11	JEWITT GPW	45	0,96%	8,49	382	33	8,6%	13	UKZN	South Africa	Yes
12	KFIR R	39	0,84%	10,05	392	22	5,6%	10	CSIR and WRC	South Africa	No
13	LOEWENTHAL RE	38	0,81%	35,13	1 335	58	4,3%	17	UCT	South Africa	No
14	XU YX	38	0,81%	4,58	174	22	12,6%	7	UWC	South Africa	No
15	MAREE JP	37	0,79%	10,92	404	27	6,7%	13	CSIR and WRC	South Africa	No
16	STEPHENSON D	34	0,73%	7,62	259	8	3,1%	9	WITS	South Africa	No
17	VAN ZYL JE	33	0,71%	12,73	420	53	12,6%	10	UJ and UCT	South Africa	No
18	MOMBA MNB	32	0,69%	13,94	446	27	6,1%	13	TUT	South Africa	No
19	VAN KOPPEN B	32	0,69%	7,72	247	26	10,5%	9	IWMI	South Africa**	No
20	PRINSLOO JF	31	0,66%	7,06	219	80	36,5%	9	UL	South Africa	No
21	SCHULZE RE	31	0,66%	12,71	394	16	4,1%	12	UP	South Africa	No
22	BROUCKAERT CJ	30	0,64%	9,37	281	6	2,1%	9	UKZN	South Africa	No
23	JAMES CS	30	0,64%	15,27	458	23	5,0%	10	UJ	South Africa	No
24	PEGRAM GGS	29	0,62%	20,14	584	27	4,6%	16	UKZN	South Africa	No
25	PRETORIUS WA	29	0,62%	10,24	297	18	6,1%	10	UP	South Africa	No

Rank	Authors	Publications	% of 6 532 publications	Average citations per item	Times cited	Self-citations	Self-citations as % of articles	*h*-index	Organisation	Country	WARFSA Publication association
26	VENTER SN	28	0,60%	16,11	451	14	3,1%	10	UP	South Africa	No
27	MSAGATI TAM	27	0,58%	4,07	110	6	5,5%	6	UJ	South Africa	No
28	SANDERSON RD	27	0,58%	10,04	271	21	7,7%	10	SU	South Africa	No
29	ANNANDALE JG	26	0,56%	10,19	265	34	12,8%	10	UP	South Africa	No
30	BUX F	26	0,56%	17,46	454	13	2,9%	13	DUT	South Africa	No
31	FATOKI OS	26	0,56%	17,00	442	18	4,1%	13	CPUT and UV	South Africa	No
32	VAN RENSBURG LD	25	0,54%	4,08	102	23	22,5%	6	UFS and CSIR	South Africa	No
33	WEPENER V	25	0,54%	9,08	227	11	4,8%	9	NWU and UNIZULU	South Africa	Yes
34	ASHTON PJ	24	0,51%	13,58	326	8	2,5%	11	CSIR and WRC	South Africa	No
35	NGILA JC	24	0,51%	5,79	139	2	1,4%	6	UJ and UKZN	South Africa	No
36	BRITZ TJ	23	0,49%	8,78	202	31	15,3%	9	SU	South Africa	No
37	ADAMS JB	22	0,47%	10,73	236	20	8,5%	8	NMMU	South Africa	No
38	SMITHERS JC	22	0,47%	10,14	223	16	7,2%	7	UKZN	South Africa	No
39	TUTU H	22	0,47%	2,77	61	4	6,6%	4	WITS	South Africa	No
40	WIECHERS HNS	22	0,47%	0,73	16	3	18,8%	3	WRC	South Africa	No
41	DOLD PL	21	0,45%	59,10	1 241	23	1,9%	11	UCT	South Africa	No
42	EHLERS MM	21	0,45%	15,38	323	9	2,8%	10	UP	South Africa	No
43	SCHOEMAN JJ	21	0,45%	13,43	282	9	3,2%	9	CSIR and UP	South Africa	No
44	SCHUTTE CF	21	0,45%	17,19	361	1	0,3%	8	UP	South Africa	Yes
45	WALKER S	21	0,45%	9,24	194	7	3,6%	10	UFS	South Africa	Yes
	TOTAL	1 824	39,09%		27 482	2618					
	AVERAGE			13,52	610,71	58,18	8,4% (SA 4,4%)				

Note: Where researchers from other countries other than South Africa are indicated, those typically indicate research collaborations.

** IMWI is an international research institute, with offices in South Africa.

Source: Clarivate Analytics™ Web of Science™

Key:

CPUT – Cape Peninsula University of Technology

CSIR – Council for Scientific and Industrial Research

DUT – Durban University of Technology

IWMI – Int Water Management Institute

NMMU – Nelson Mandela Metropolitan University

NWU – North-West University

RU – Rhodes University

SU – Stellenbosch University

UCT – University of Cape Town

UFS – University of the Free State

UJ – University of Johannesburg

UKZN – University of KwaZulu-Natal

UL – University of Limpopo

UNIZULU – University of Zululand

UP – University of Pretoria

UV – University of Venda

UWC – University of the Western Cape

Wits – University of the Witwatersrand

WRC – Water Research Commission

Following the analysis of publication records of these researchers, the network visualisation of these researchers is presented in Figure 9.5. Here it becomes evident that strong research networks exist around Prof. Ekama and Prof. Wentzel (UCT), Prof. Buckley (UKZN), Prof. Hughes (RU), Prof. Mamba (UJ) and Prof. Grabow and Prof. Cloete at UP.[32] It is further evident that there are co-publishing links between researchers from different institutions, however to a limited extent, given the limited links observed between researchers from different institutions in Figure 9.5.

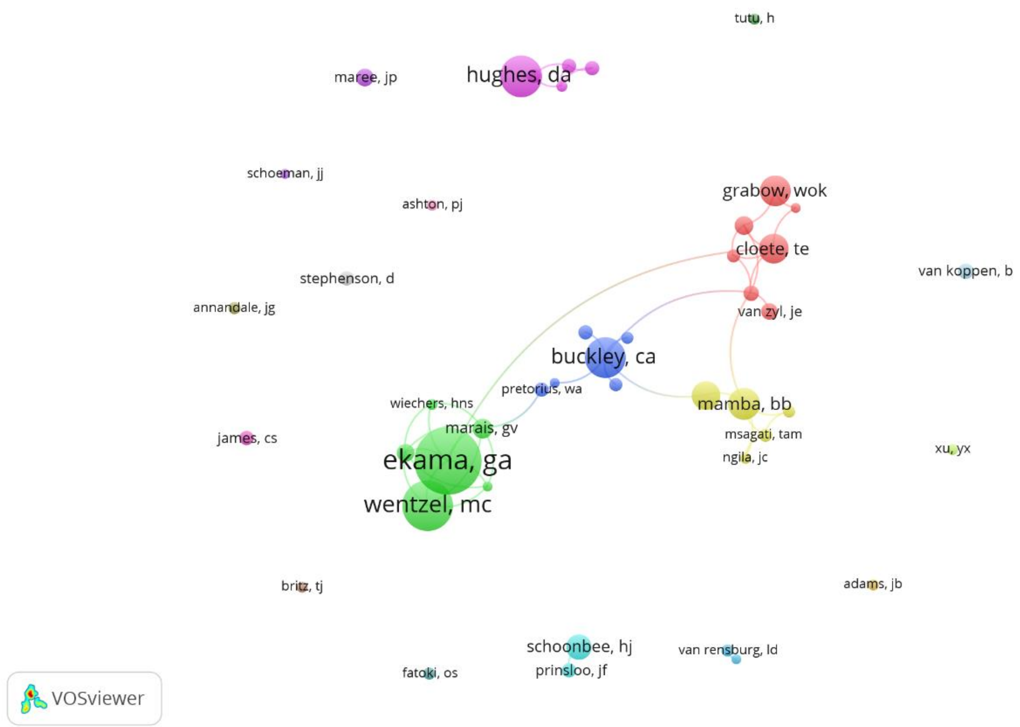


Figure 9.5: Author network visualisation of South African water researchers that have published more than 20 publications each (1980–2016)

Source: Clarivate Analytics™ Web of Science™

The findings above, and especially relating to the institutions and authors that have been contributing large numbers of publications to the South African water sector, are in line with previous studies undertaken by Prof. Pouris and colleagues (Jacobs, Pouris et al., 2014; Pouris, 2013, 2015).

Having established the extent of water research in South Africa, and a discussion on the more prolific water researchers from South African institutions, our focus now shifts towards authorship trends. The following section presents a discussion of these authorship trends

[32] Prof. Cloete has subsequently relocated to the University of Stellenbosch.

through an analysis of the number of authors per publication over time, and sections relating to the countries with which South African researchers co-publish water research.

9.2.2 Co-publication trends in South African water research publications

In a previous study, Boshoff (2009) concluded that in general, researchers in the SADC region have increased co-authorship of publications, with marked increases observed since the mid-1990s. In addition, Boshoff (2010) and Pouris and Ho (2013) concluded that, in general, there has been a major decline of single-authored articles from many African countries and also in the SADC region. Sooryamoorthy (2009) also found that South African articles published between 2000 to 2005, 88% were co-publications.

With this chapter having a specific focus on water research in South Africa, the following section will analyse bibliometric data of the number of authors per water research publication involving at least one author from a South African institutions, for the period 1980 to 2016, to determine what trends could be established.

9.2.2.1 Number of authors per publication

In this section, the number of authors per publication is analysed, with the results presented in Figure 9.6. Here it is evident that in general, co-authored articles have increased since the early-to-mid-2000s, with publications with four authors increasing substantially since 2010. In addition, publications between two researchers have generally dominated publications between 1980 and the mid-2000s, although the general declining trend is observed. Since 2014, there has been a marked decline in publications with two authors, with a 15% decline in these publications between 2014 and 2016. Also significant, is the number of articles with more than five authors, increasing significantly since 2000. It is clear that 75% of water research publications are articles with more than three co-authors in 2016 – note the significant increase in publications with three authors in 2016. Moreover, 24% of water research articles in South African in 2016 comprised of five and more authors, and single-authored articles, having declined in recent years, comprised less than 10% of publications in 2016.

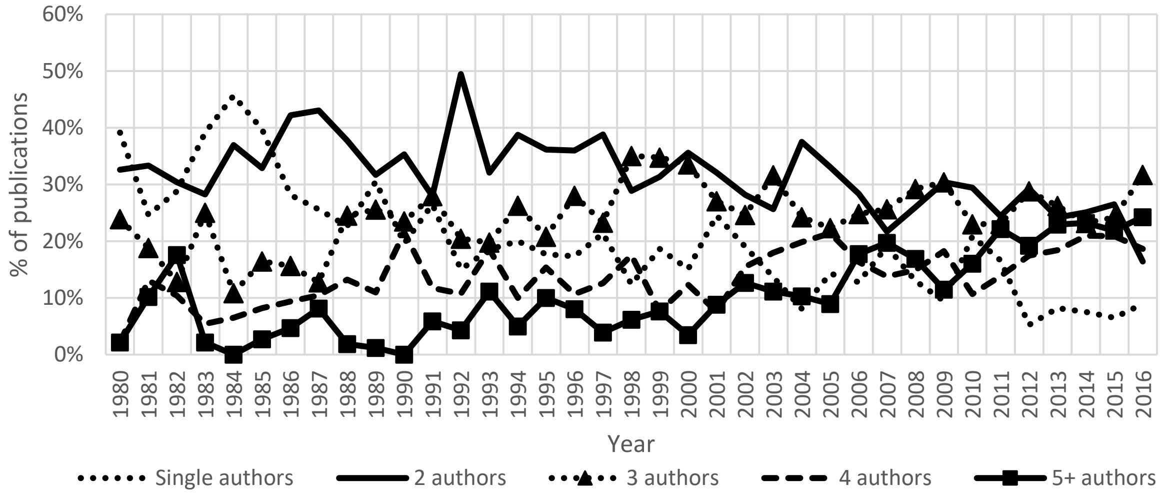


Figure 9.6: Co-authorship trends of South African Water research publications (1980–2016)

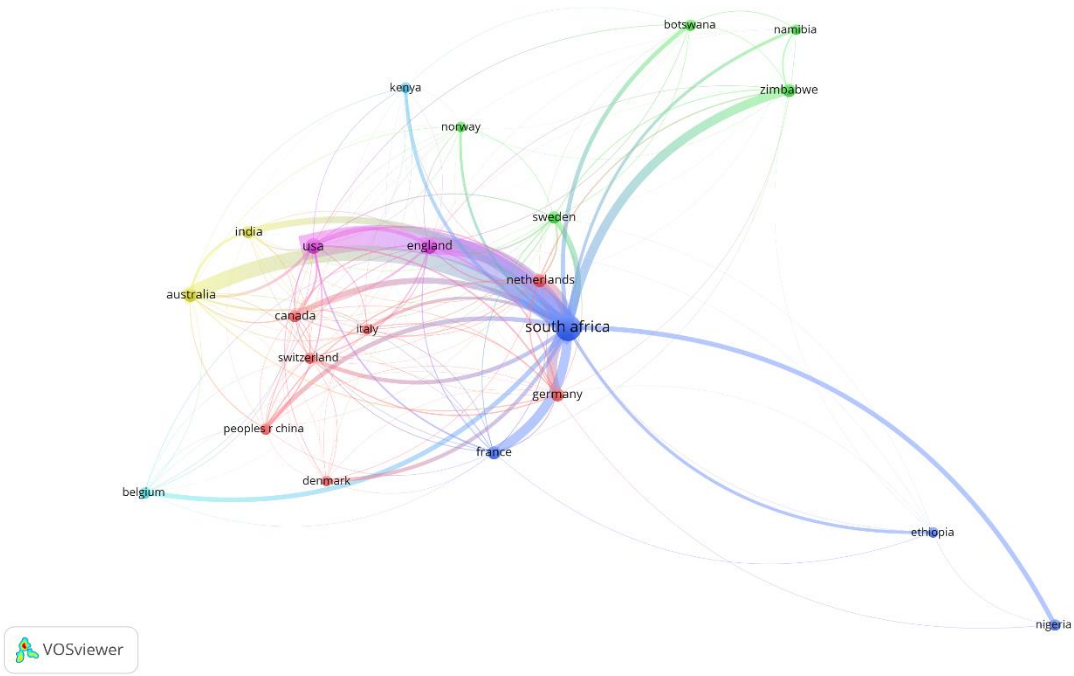
Source: Clarivate Analytics™ Web of Science™

Single-authored water research publications have been declining over the time period analysed, with publications with between two and four authors increasing significantly. Also significant, is the increase in publications with more than five authors over the years. These increases in multiple-authored water publications are in line with the general increases in research in the region, as established by Boshoff (2010) and Pouris and Ho (2013). Further analysis of the countries with which South African water researchers co-publish are discussed in the next section.

9.2.2.2 Co-authorship countries

In the previous chapter, it was shown that South African water researchers have co-authored publications mostly with researchers from other institutions in South Africa (74%), followed by researchers from beyond the SADC (20%) and then lastly, to a very limited extent, in the SADC region (3%). As already evident from the previous sections, there are no researchers from outside South Africa amongst the researchers who have published more than 20 water research articles between 1980 and 2016 along with South African institutions. This would confirm the findings earlier that water researchers in South Africa mostly collaborate with researchers in South Africa. Moreover, Pouris (2015) established that 35% of water-related publications produced by South African water researchers had international co-authors, with the top collaborating countries being the United States, United Kingdom (England), Australia and the Netherlands.

By making use of VOSviewer® data visualisation software, the most prominent water research co-authorship countries that collaborate with South Africa are highlighted and presented in Figure 9.7. An initial analysis identified 104 countries, which have contributed at least one publication with South African water researchers. When the analysis parameters in the VOSviewer® software were set at a minimum number of 20 publications, this resulted in 22 countries meeting this threshold, which assists in identifying the most prominent network countries. Figure 9.7 further graphically presents various aspects, such as the dominant countries with which South African water researchers co-author publications. In addition, the thickness of the line between countries indicates the relative extent of co-authorship.



Min count of articles between countries: 20

Figure 9.7: Country network visualisation: Co-authorship of water research in the South African water sector (1980–2016)

Data source: Clarivate Analytics™ Web of Science™ and analysed with VOSViewer®

- **Dominant co-authorship countries:** From Figure 9.7, it is clear that the most prominent SADC countries (in geographical order and not considering the strength of the association at this stage) with which South African water researchers co-author publications are Botswana, Zimbabwe and Namibia. Beyond the SADC, and still on the African continent, countries are Nigeria, Kenya and Ethiopia. Other prominent countries beyond the African continent are Denmark, Belgium, Unite Kingdom (England), France, Switzerland, the Netherlands, Sweden, Germany, Italy and Norway in Europe. In Australasia, prominent countries are India, the People's Republic of China, and Australia. In North America, prominent countries are the United States and Canada.

- **Dominant co-authorship associations (strength of country association):** Figure 9.7 further provides a graphical presentation of the relative strength of the co-author collaboration between South African water researchers and other countries. This is presented through the thickness of the line between countries, where a thicker line indicates a larger co-operation. Here the relative strong co-author association between South African water researchers and countries such as the United States, United Kingdom (England), Australia, France, Germany, the Netherlands, Zimbabwe and India becomes evident.

However, this section only provides a relative graphical presentation of prominent countries with which South African water researchers co-publish, with more detail on the full extent presented in the next section.

9.2.2.3 Detail of South African water research co-authorship collaboration

This section presents more information on the countries with which South African water researchers have co-authored publications over the study period. The section starts by first presenting the scope of the general priority research areas in South Africa. This provides the context in which South African water research finds itself. The section further presents detail of the countries with which South African water researchers have co-authored water research articles.

The top research areas in South Africa have been diverse, and were Engineering, Medicine, Chemistry, Environmental Sciences, Physics, related topics in Science and Technology, Plant Sciences, Zoology, Agriculture and Mathematics (Table 9.2). Water research is further ranked in the first quadrant amongst 151 research areas in South Africa, with water research comprising 1,75% of all publications in this field. At this point, it is important to refer to the AI analysis of water research publications undertaken in the previous chapter, which suggests that the relative effort South African researchers made in water research, when compared to other research areas in the country, has declined slightly in recent years, and marginally less than the SADC average (refer to Section 7.2.2 in Chapter 7). Finally, within the SADC region, researchers affiliated with South African institutions have contributed the most research by far in the region, contributing 81,4% of all research between 1980 and 2016.

Table 9.2: Top 10 research areas: South Africa (1980–2016)

Rank	Research areas	% of country research	% of SADC
1	ENGINEERING	7.26	
2	GENERAL INTERNAL MEDICINE	7.06	
3	CHEMISTRY	5.69	
4	ENVIRONMENTAL SCIENCES ECOLOGY	5.24	

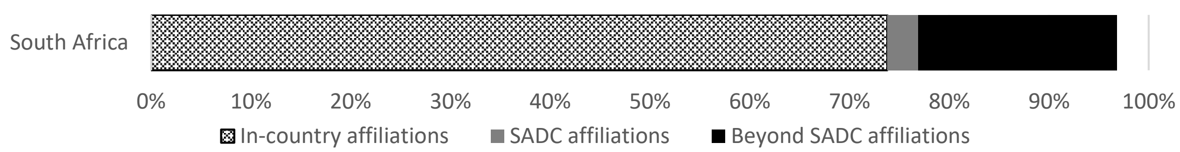
Rank	Research areas	% of country research	% of SADC
5	PHYSICS	4.65	
6	SCIENCE TECHNOLOGY OTHER TOPICS	4.48	
7	PLANT SCIENCES	4.46	
8	ZOOLOGY	2.97	
9	AGRICULTURE	2.87	
10	MATHEMATICS	2.83	
26/151 (Q1)	WATER RESOURCES	1.75	
	ALL RESEARCH		81.4%

Source: Clarivate Analytics™ Web of Science™

The results of individual country affiliations of water researchers that have published water research in South Africa between 1980 and 2016 are presented in Table 9.3. The number of affiliations is presented in three categories, namely all research affiliations, SADC countries and beyond the SADC. The countries are ranked from 1 to 5 with, Rank 1 being the country or countries with the most author affiliations, followed by Ranks 2 to 5. The balance of the author–country affiliations was calculated as 'other'. The objective was to present the top-ranked countries with which South African water researchers have co-authored publications with, followed the SADC countries and countries beyond the SADC.

Table 9.3: Country affiliations of water research in the South Africa (1980–2016)

Research affiliations	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Other	Total of affiliations	Number of water research publications (% of SADC)
All research affiliations	South Africa (4 666)	United States (209)	United Kingdom (England) (134)	Australia (122)	Germany (81)	1 112	6 324	4 666 (81,4%)
SADC countries	Zimbabwe (68)	Botswana (31)	Namibia (24)	Tanzania (19)	Malawi (16)	37	195	
Beyond the SADC	United States (209)	United Kingdom (England) (134)	Australia (122)	Germany (81)	Netherlands (80)	635	1 261	



Note: Due to fractional counting, the co-authored articles were assigned to each country, resulting in the percentages not always counting up to 100%

Source: Clarivate Analytics™ Web of Science™

From Table 9.3, it becomes evident that South African water researchers co-publish more with researchers beyond the SADC than within the SADC region, and with researchers from countries such as the United States, United Kingdom (England), Australia, Germany and the Netherlands. Figure 9.8 provides the distribution of these top five countries for the period between 1980 and 2016. Here it becomes evident that since the turn of the century, an increase has occurred in the annual publication of water research with these top five countries, with the United States consistently being one of the top countries – even indicating more significant increases from 2010 to 2016. Water research with Australian researchers has also increased since the mid-1990s, with significant increases in 2006 and 2014, and research together with German institutions increasing since the mid-2000s. One could conclude that in general, South African researchers consistently continue to co-author water research with the top countries beyond the SADC, with significant increases by these countries in most recent years.

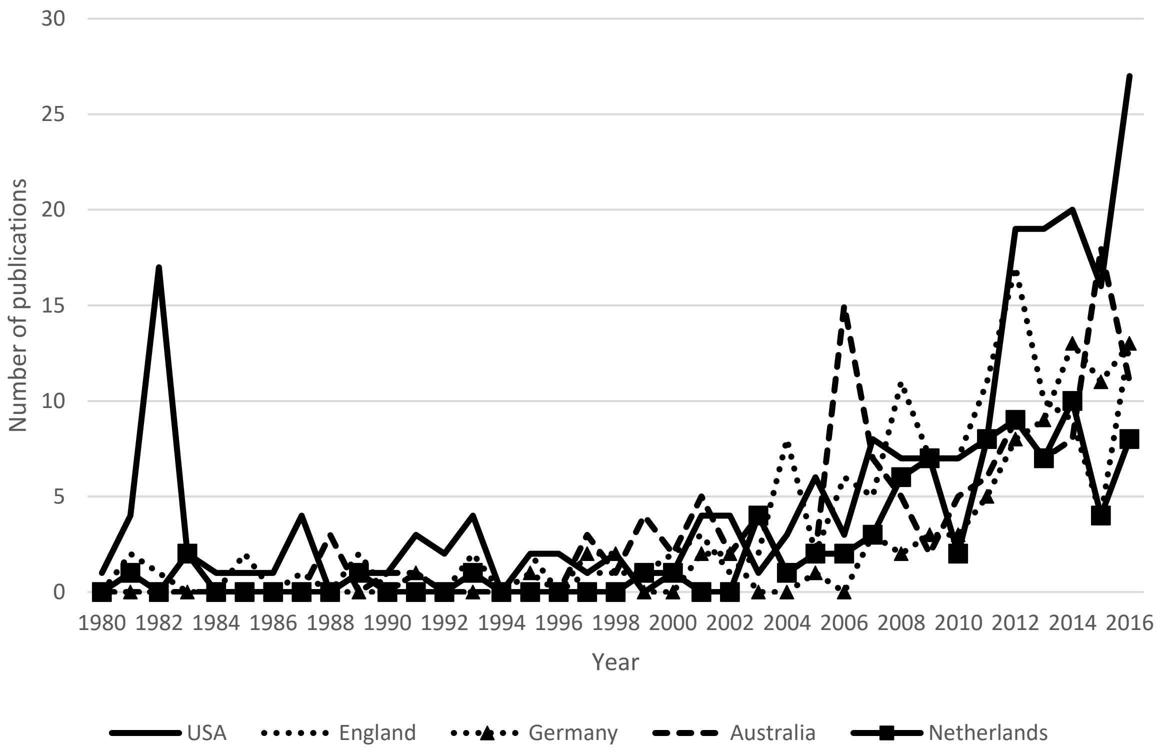


Figure 9.8: Annual distribution of publications from top five countries which co-author water research with South Africa (1980–2016)

Source: Clarivate Analytics™ Web of Science™

When one further considers the top five SADC countries, with which South African researchers co-publish water research as identified in Table 9.3, these countries are, in rank order from 1 to 5, Zimbabwe, Botswana, Namibia, Tanzania and Malawi. Again, the annual distribution of these top five SADC countries is presented in Figure 9.9, where it becomes evident that, as in the case with the top countries beyond the SADC, the top SADC countries have seen increases since the turn of the century. The most significant increases in recent years were seen in terms of Zimbabwe, Namibia and Botswana. Moreover, one could consider that co-incidentally, these are the SADC-ExSA countries with high AIs (reflecting relative effort in relation to other research in the specific countries) in water research, as established in the Chapter 7 (see section 7.2.2).

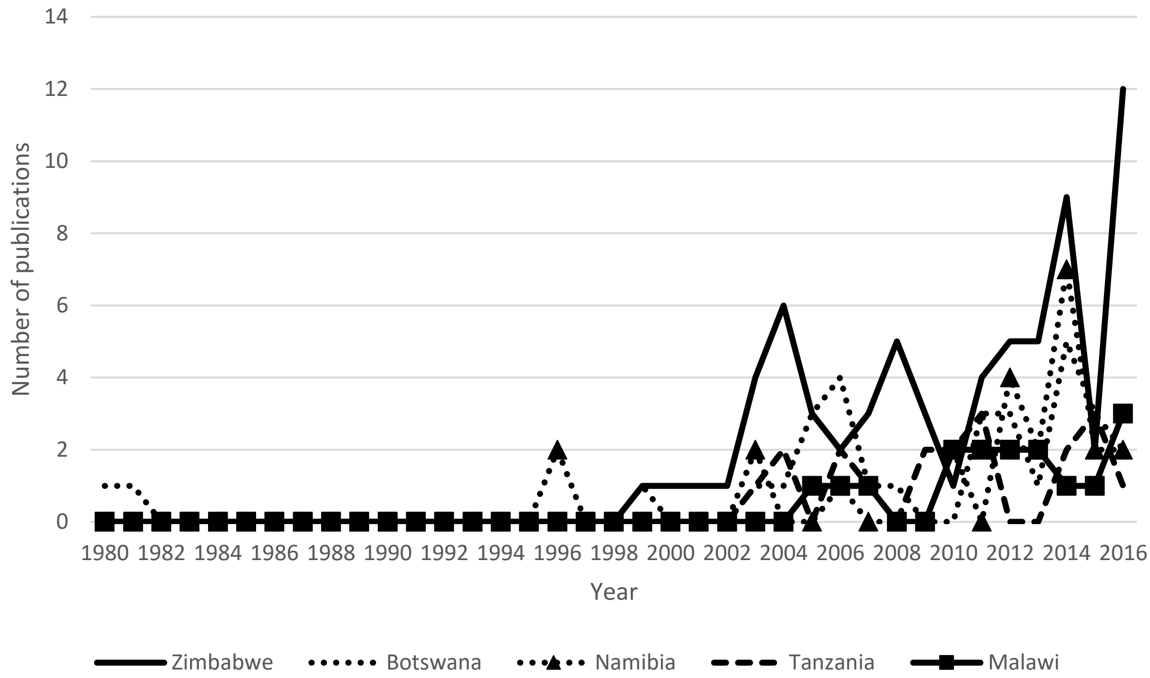


Figure 9.9: Annual distribution of publications from top five SADC countries which co-author water research with South Africa (1980–2016)

Source: Clarivate Analytics™ Web of Science™

As we have established, South African water researchers have increased the number of co-published articles over the past few years, and especially since the turn of the century. These increases have mainly been with countries beyond the SADC and with some countries in the SADC region. By briefly comparing the number of annual publications for the top countries beyond the SADC (Figure 9.8) with the top countries in SADC (Figure 9.9), it becomes evident that the annual distribution of countries beyond the SADC is higher than the SADC countries. Figure 9.10 provides a better indication of just how significant the rate at which South African researchers have co-authored publications with researchers from beyond the SADC has been, when one considers the annual share of publications with researchers from the SADC region and beyond the SADC. Even though steady increases in publications from other SADC countries have occurred since the turn of the century, it has not been as significant as with countries beyond the SADC. In the case of countries beyond the SADC, steady increases started around the mid-1990s. This could be attributed to the change in the South African democracy when research with other countries increased following the first democratic elections in South Africa in 1994, as also observed by Boshoff (2009) and Siebrits, Winter and Jacobs (2014). Moreover, it is further evident from Figure 9.10, that since 2009, the rate at which South African researchers have co-authored publications with countries beyond the SADC, has increased dramatically as a share of all publications in South Africa. In fact, in 2016, as much as 45% all water research publications produced in South Africa were co-authored with researchers affiliated with institutions beyond the SADC, whereas 7,5% co-authored with researchers in the SADC region. Considering that Sooryamoorthy (2009) found that 48% of all South African research produced between 2000 and 2005 was done with international collaborators, this is probably not surprising. It thus becomes evident that South African water researchers further have a preference to co-publish with countries in the global North, referring to the United States, the United Kingdom (England), Germany and the Netherlands. One reason this could be the ability of the North to mobilise large amounts of funding for the advancement of global science development (Boshoff, 2010).

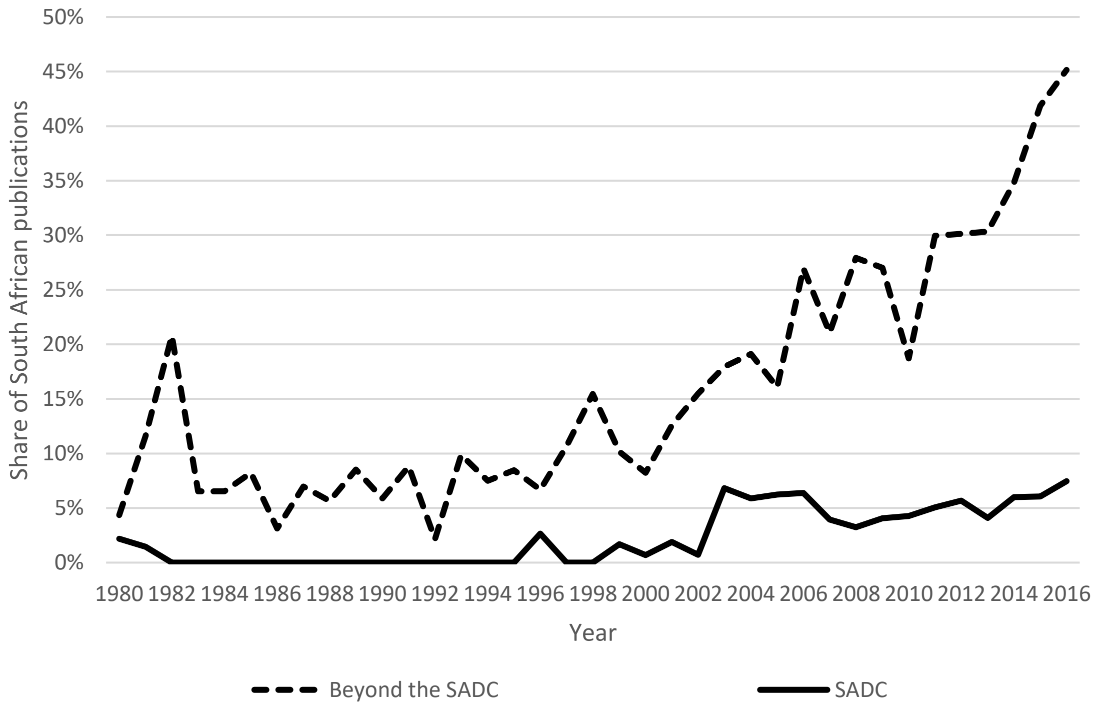


Figure 9.10: SADC and beyond the SADC country share of South African water research (1980–2016)

Source: Clarivate Analytics™ Web of Science™

As established earlier in this section, South African water researchers have, between 1980 and 2016, participated in significant co-publication of water research between certain countries. In the SADC region, the top countries are Zimbabwe, Botswana, Tanzania, Namibia and Malawi, and beyond the SADC, the top countries are the United States, United Kingdom (England), Germany, Australia and the Netherlands. Most recently, since around 2009, there has been further significant increases in water research, especially with countries beyond the

SADC. The following section will focus specifically on this most recent period – between 2009 and 2016 – to investigate which countries have been the dominant countries of collaboration, in order to ascertain whether other countries have emerged. An analysis of the bibliographic data is presented in Table 9.4, where, for each year between 2009 and 2016, the five top-ranked countries are presented.

Table 9.4: Top five water research South African co-author countries (2009–2016)

Year	Country(s) rank 1	Country(s) rank 2	Country(s) rank 3	Country(s) rank 4	Country(s) rank 5
2009	United Kingdom (England)/ Netherlands/United States (7)	Belgium (4)	Canada/ Germany/ Zimbabwe (3)	Ethiopia/Italy/ Norway/ Switzerland/ Tanzania (2)	France/Congo/ Ireland/Israel/ Kenya/Lesotho/ Mozambique/ Nigeria/PRC/ Sweden/Ukraine (1)
2010	United Kingdom (England)/ United States (7)	Australia (5)	Denmark (4)	France/ Germany/Nigeria (3)	Canada/Ethiopia/ India/Malawi/ Namibia/ Netherlands/Spain/ Switzerland/Tanzania (2)
2011	United Kingdom (England) (11)	Netherlands/United States (8)	Australia (6)	Germany/PRC (5)	Ethiopia/France/ Nigeria/Sweden/ Zimbabwe (4)
2012	United States (19)	UK (England) (19)	Australia/ Netherlands (9)	Germany (8)	Belgium/ France/ India (6)
2013	United States (19)	UK (England) (10)	Germany (9)	Australia/France/ Netherlands/ Sweden (7)	PRC (6)
2014	United States (20)	Germany (13)	France (11)	Netherlands (10)	Zimbabwe (9)
2015	Australia (18)	India/United States (16)	Germany (11)	France/Nigeria (6)	Canada/UK (England)/Kenya (4)
2016	United States (27)	United Kingdom (England)/Germany (13)	Zimbabwe (12)	Australia (11)	India (10)

Source: Clarivate Analytics™ Web of Science™

From Table 9.4 it becomes evident that:

- South African water researchers continue to co-publish research with traditional countries such the United States, United Kingdom (England), Germany, Australia and the Netherlands, as identified earlier in this section.

- France is emerging as a country with which South African water researchers increasingly co-publish, as it appears more frequently amongst the top five countries.
- India and the People's Republic of China have further emerged as countries in the Global South with which South African water researchers tend to co-author water research on a regular basis, in most recent years.
- There are other countries on the African continent, such as Nigeria and Kenya, and to a certain extent Ethiopia, which have been in the top water research collaborating countries with South African water researchers.

To conclude this section, water research in South Africa is diverse, and one where water research is one of the higher-ranked research fields in terms of research output. It is further evident that South African water researchers tend to co-publish increasingly with more than two co-authors. These publications have predominantly been with countries in the developed Global North, and specifically the United States, the United Kingdom (England), Germany and Australia. Co-author collaboration with researchers from the SADC region has been limited, and predominantly with Zimbabwe, Botswana, Namibia, Tanzania and Malawi. In the most recent years, these countries have mostly remained the same. However, researchers from France (from the developed Global North), and India and the People's Republic of China in the developing South, further feature amongst countries who co-publish more regularly with South African water researchers.

Our attention now moves to the following section, analysing the citation trends of water research as published by South African researchers.

9.3 Citation analysis of water research publications in the South African water sector

In the earlier sections of this chapter, it was evident that water research publication output in South Africa has increased over the years, with more than 260 water research publications produced in 2016. As is evident in Figure 9.11, there have been years such as 1986, the early 1990s, the late 1990s and 2001 and 2003, when articles from those years were cited more often than during other years. This might be attributed to some publications from the specific years that have been cited regularly over the years, thus increasing average citation score for the publications of that particular year. Moreover, if one further considers the average citation score, it becomes evident that there has been a general decline in the average citation of water research publications since 2003, even considering that a time lag occurs between when research is published and when it is cited. The aim of this section is to assess the citation trends in detail.

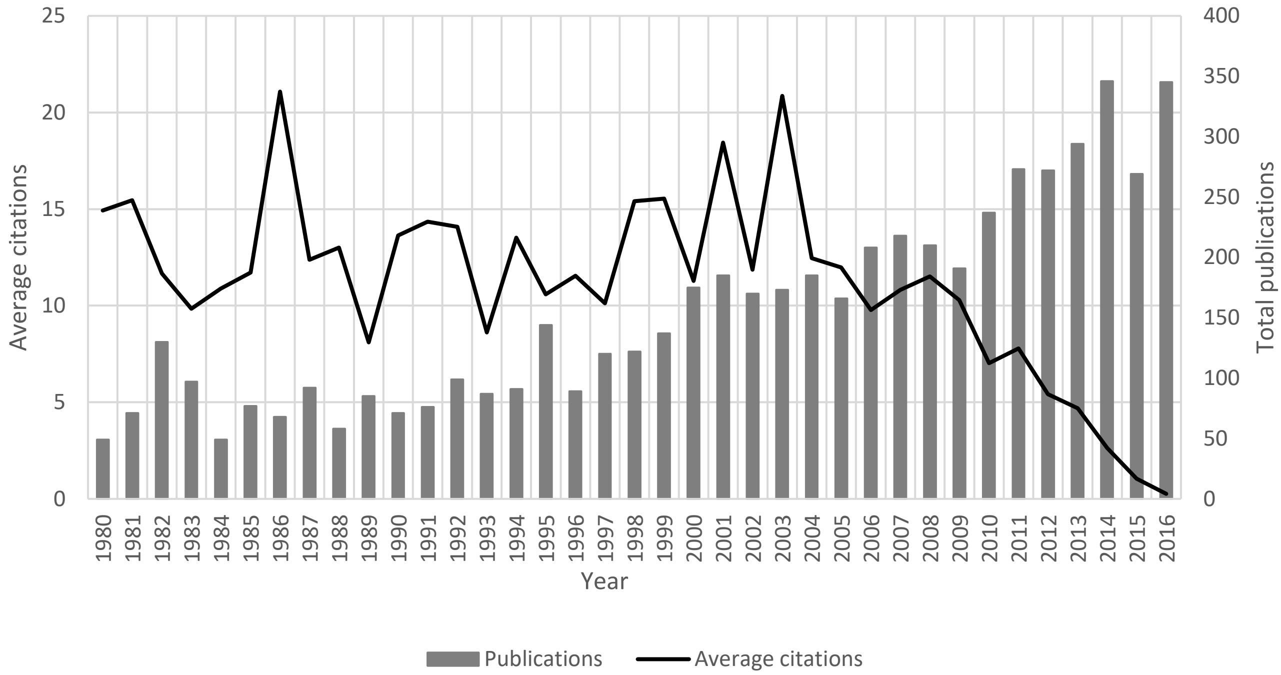


Figure 9.11: Average citation score of South African water research articles in relation to the total number of articles published (1980–2016)

Source: Clarivate Analytics™ Web of Science™

From Table 9.5, it is evident that the 4 666 water research publications produced between 1980 and 2016 have been cited 45 079 times,[33] at an average annual rate of 9,66 times per article. Table 9.5 and Figure 9.15 further present the publication and citation distribution of water research in South Africa in citation ranges of 10, 100 to 500 and more than 500.

Table 9.5: Distribution of South African water research publications and citations (1980–2016)

Citation range	Number of publications	% of publications	Number of citations	% of citations	Citation rate
0	1 165	24,97%	0	0,0%	
1–10	2 409	51,63%	9 835	21,8%	4,08
10–20	592	12,69%	8 673	19,2%	14,65
20–30	199	4,26%	4 943	11,0%	24,84
31–40	97	2,08%	3 461	7,7%	35,68
41–50	62	1,33%	2 828	6,3%	45,61
51–60	43	0,92%	2 396	5,3%	55,72
61–70	26	0,56%	1 691	3,8%	65,04
71–80	11	0,24%	821	1,8%	74,64
81–90	17	0,36%	1 445	3,2%	85,00

33 Include self-citations.

Citation range	Number of publications	% of publications	Number of citations	% of citations	Citation rate
91–100	8	0,17%	775	1,7%	96,88
100–500	34	0,73%	6 136	13,6%	180,47
500+	3	0,06%	2 075	4,6%	691,67
Totals	**4 666**	**100%**	**45 079**	**100%**	
Average citation rate			**9,66**		

Source: Clarivate Analytics™ Web of Science™

Here it further becomes evident that 25% of water research published by South African institutions has never been cited, which is normal, as not all publications are always cited. It is further evident that just over half of all publications (52%) have been cited between one and ten times, at an average citation rate of 4,11 per article. There are a further 37 publications, which received more than 100 citations each. These publications account for only 0,79% of all publications, and received 18,2% of all citations, and will be investigated further in this section.

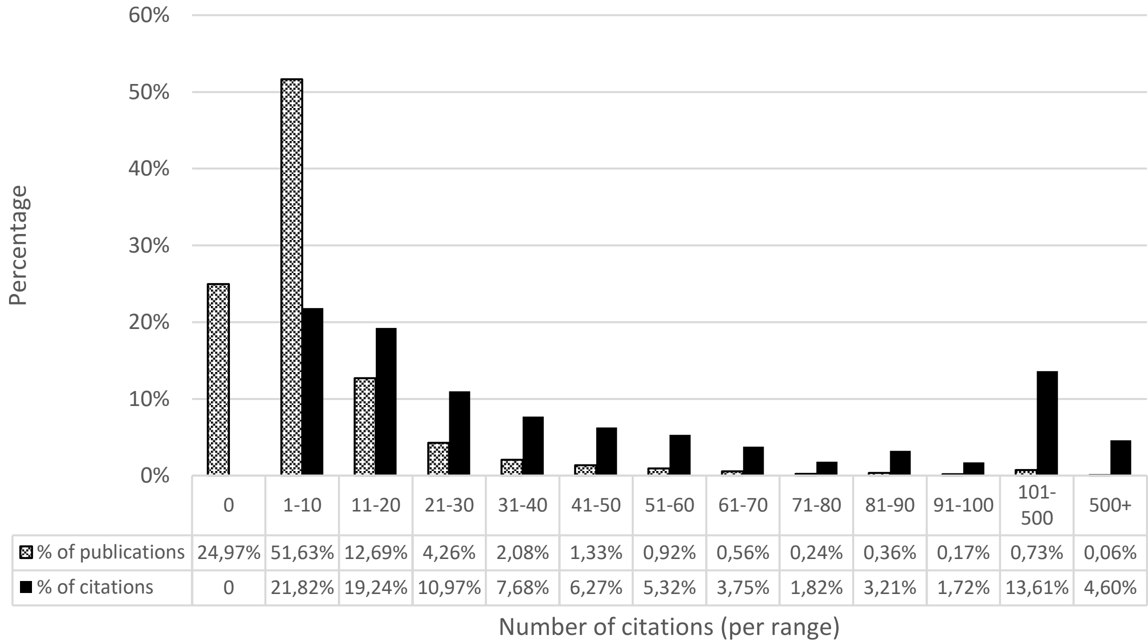


Figure 9.12: Distribution of South African water research publications and citations (1980–2016)

Source: Clarivate Analytics™ Web of Science™

9.3.1 Citation impact

As also indicated in the previous chapter (section 8.4.1), the citation score and citation rate provides an indication of the frequency at which an average article is cited. However, due to factors which include the degree to which references from other fields are cited, differences amongst fields in the average number of cited references per publication, the way the number of citation always increase over time and the average age of cited references, citation scores are normalised by calculating the mean normalised citation score (MNCS) (Leydesdorff et al., 2011; Waltman et al., 2011). For a more detailed discussion on the MNCS, refer to section 5.3.2.1).

Considering citation data from water research emanating from South African universities and research institutions, the average annual citation scores is presented in Table 9.6 for the period between 1980 and 1999 and in Table 9.7 for the period between 2000 and 2016, with the annual distribution of citation data presented in Figure 9.13, where citation scores were normalised by the number years and presented as the average annual citation rate. In addition, the MNCS-values of water research in South Africa are also listed in Table 8.6 and Figure 8.16.

If one were to first consider the annual citation scores (Figure 9.13), it is evident that the annual number of publications has gradually increased over the years, from 46 in 1980 to a point in 2001 where the number of publications increased to above 150 for the first time. These publications were increasingly cited, along with the gradual increase in publications. After 2001, the total number of water research publications declined slightly to 112 publications in 2005, after which it gradually increased to 268 publications in 2016. During this time, after the turn of the century, the average annual citation rate remained constant between 1,49 in 2003 and 8,89 (in 2006), and only continuously declining since 2013 – this can be attributed to the time lag it takes between the publication of articles, and the citation of these articles.

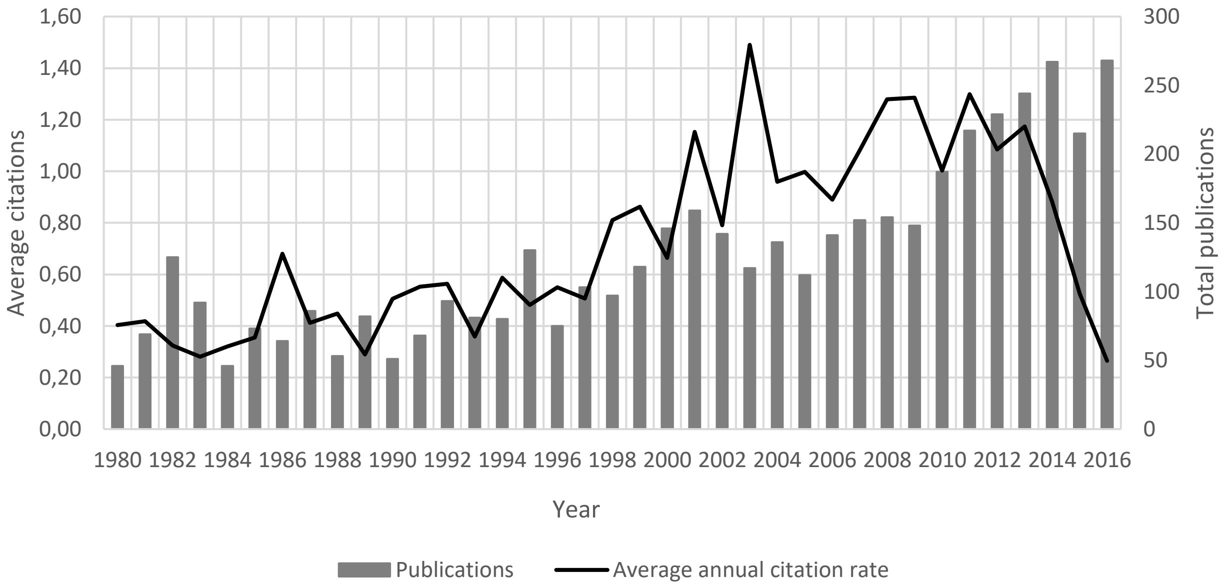


Figure 9.13: Average annual citation rate of South African water research (1980–2016)

Source: Clarivate Analytics™ Web of Science™

Table 9.6: Citations of South African water research publications (1980–2000)

Year	Total publi-cations (A)	Citations per year																					Total number of citations (1980–2016) (B)	Average number of citations (1980–2016) C=(B/A)	Average annual citation rate (D=C/nr.of years)
		80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00			
1980	46	5	37	24	20	16	15	30	20	18	17	12	24	24	14	15	20	19	27	18	19	14	687	14,93	0,40
1981	69	0	8	39	53	42	56	41	37	25	19	24	29	33	23	18	23	22	22	37	32	19	1 067	15,46	0,42
1982	125		0	21	44	27	38	35	38	16	24	20	28	17	22	24	19	32	32	26	28	34	1 459	11,67	0,32
1983	92			0	7	46	64	44	28	34	27	23	34	36	28	31	25	34	36	28	32	23	906	9,85	0,28
1984	46				0	17	18	34	37	15	15	16	22	18	11	15	16	18	22	17	18	10	501	10,89	0,32
1985	73					0	4	49	49	48	37	23	35	34	29	34	22	34	36	44	39	33	855	11,71	0,35
1986	64							15	46	43	41	40	56	40	31	64	50	54	57	60	69	43	1 349	21,08	0,68
1987	86								7	47	36	33	26	48	34	39	22	39	35	31	42	37	1 064	12,37	0,41
1988	53									6	36	29	36	30	21	32	32	35	29	30	31	25	689	13,00	0,45
1989	82										12	39	40	42	33	34	31	33	25	23	32	22	665	8,11	0,29
1990	51											3	33	17	26	27	22	24	29	16	31	28	695	13,63	0,50
1991	68												8	53	50	54	40	49	43	34	47	53	976	14,35	0,55
1992	93													3	67	59	50	55	46	64	62	56	1 309	14,08	0,56
1993	81														24	36	27	24	20	28	20	25	698	8,62	0,36
1994	80															4	35	43	47	56	65	62	1 081	13,51	0,59
1995	130																7	79	57	57	76	62	1 377	10,59	0,48
1996	75																	18	32	50	53	41	866	11,55	0,55
1997	103																		10	48	44	47	1 043	10,13	0,51
1998	97																			4	48	41	1 494	15,40	0,81
1999	118																				34	41	1 833	15,53	0,86
2000	146																					22	1 647	11,28	0,66
TOTAL		**5**	**45**	**84**	**124**	**148**	**195**	**248**	**262**	**252**	**264**	**262**	**371**	**395**	**413**	**486**	**441**	**612**	**605**	**671**	**822**	**738**	**22 261**	**12,52**	

Note: This table should be read in conjunction with Table 9.7

Source: Clarivate Analytics™ Web of Science™

Table 9.7: Citations of South African water research publications (2001–2016)

		Citations per year																		
Year	**Total publi-cations (A)**	**01**	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**Total number of citations (2001–2016) (B)**	**Average number of citations (2001–2016) (C=B/A)**	**Average annual citation rate (D=C/nr. of years)**
2001	159	17	85	99	125	119	142	206	192	218	217	219	254	251	240	262	286	2 932	18,44	1,15
2002	142		7	45	76	95	87	136	130	127	124	148	125	140	143	146	155	1 684	11,86	0,79
2003	117			17	63	93	162	153	179	201	213	200	226	232	243	244	215	2 441	20,86	1,49
2004	136				12	58	113	144	141	135	145	156	147	178	137	167	162	1 695	12,46	0,96
2005	112					15	64	110	107	122	125	117	142	132	139	133	135	1 341	11,97	1,00
2006	141						22	84	115	126	154	158	132	159	133	143	153	1 379	9,78	0,89
2007	152							30	109	171	159	179	183	190	208	201	214	1 644	10,82	1,08
2008	154								39	120	191	187	230	243	257	259	247	1 773	11,51	1,28
2009	148									52	123	162	215	215	264	262	229	1 522	10,28	1,29
2010	187										57	145	155	222	215	255	264	1 313	7,02	1,00
2011	217											49	198	310	361	365	408	1 691	7,79	1,30
2012	229												47	185	285	337	388	1 242	5,42	1,08
2013	244													71	249	407	419	1 146	4,70	1,17
2014	267														57	271	378	706	2,64	0,88
2015	215															42	184	226	1,05	0,53
2016	268																71	71	0,26	0,26
TOTAL	**2 888**	**17**	**92**	**161**	**276**	**380**	**590**	**863**	**1 012**	**1 272**	**1 508**	**1 720**	**2 054**	**2 528**	**2 931**	**3 494**	**3 908**	**22 806**	**7,90**	

Note: This table must be read in conjunction with Table 9.6

Source: Clarivate Analytics™ Web of Science™

As indicated earlier, citation values need to be corrected for field differences. The 'mean normalised citation score' (MNCS) is such a normalised indicator. An analysis of the MNCS-values for South African water research publications is presented in Table 8.6, with the annual distribution of the MNCS presented in Figure 8.16. A MNCS-value of 1 means that the citation impact of a specific set of publications (i.e. South African publications) are generating citation rates equal to the world average for publications in that field. The MNCS values for water research publications which emanated from South African universities and research institutions, were well above 1 in the early 1980s. Since then, these values steadily declined. As a result, even though the volume water research articles produced by South African water researchers has increased steadily over the years, the citation impact has declined especially since the turn of the century. This, unfortunately, means that the increased production has not occurred with a commensurate increase in visibility.

Table 9.8: Mean normalised citation scores (MNCS) of South African water research publications (1980–2016)

Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Number of publications	46	54	62	62	41	61	58	82	52	69	51	65	89	71	68	102	65	84	78	109
MNCS	1,1074	1,6755	1,1702	1,5553	1,3505	1,2342	1,2294	0,8498	1,0389	0,9589	0,7587	1,0858	0,9702	0,7504	0,7449	0,7974	0,8516	0,5850	0,5478	0,6821

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Number of publications	90	114	95	106	128	99	104	127	135	138	135	163	196	200	232	185	239
MNCS	0,7515	0,7694	0,5614	0,6018	0,5118	0,6785	0,6440	0,6879	0,7075	0,5905	0,6436	0,7186	0,5861	0,7925	0,6192	0,5075	0,5767

Note: The number of publications in Table 8.6 are fewer than the number of publications in Table 9.6 and Table 9.7, as the calculation of the MNCS only consider the number of articles, letters and reviews, whereas Table 9.6 and Table 9.7 present all document types.

Source: Clarivate Analytics™ Web of Science™ and calculated by the CREST

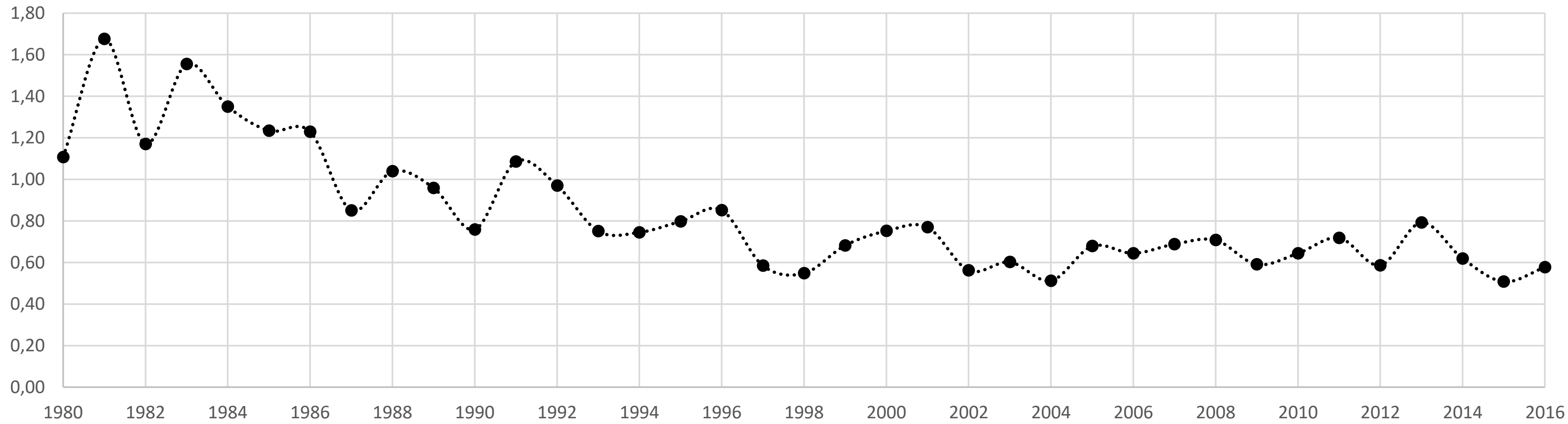


Figure 9.14: Distribution of the MNCS of Southern African water research (1980–2016)

Source: Clarivate Analytics™ Web of Science™

Earlier in the chapter (see section 9.3), it was mentioned that there were years when articles were cited more regularly presented in Figure 9.11. If one were to determine further how many water research publications from South African institutions have been cited consistently over the years, it becomes evident that only relatively few publications can be identified. Table 9.9 provides the number of publications produced between 1980 and 2016, which have received between 5 and 20 citations annually, in intervals of five citations per year. Here it is evident that 68 publications have recorded an annual average of between 5 and 20 citations per year. In addition, there are eight publications, which recorded more than 20 publications per year since their publication.

Table 9.9: Water research articles in SADC countries with an average of more than five citations per year (1980–2016)

	Annual average citation between			
	5–10 per year	**11–15 per year**	**16–20 per year**	**20+ per year**
Number of publications	58	6	4	8

Source: Calculated from data obtained from Clarivate Analytics™ Web of Science™

One can however further ask when these contributions were published, with the annual distribution of these publications presented in Figure 9.15. An increase can be observed in these publications since 1998, with 49 articles published, which were cited on average 5–20 times annually, and seven articles published with a citation average of more than 20 per year. As observed in the previous chapter, the article by Bosch and Hewlett (1982) has been cited consistently since its publication in 1982, with an average annual citation rate of 29,89. More recently, three articles have been cited regularly by scholars, namely the articles by Hrachowitz et al. (2013), McVicar et al. (2012). Montanari et al. (2013), which averaged 46, 42,4 and 39,5 citations per year since their publication in 2013 and 2012 respectively. It will be interesting to follow these articles to determine whether they can maintain the high citation rates in future.

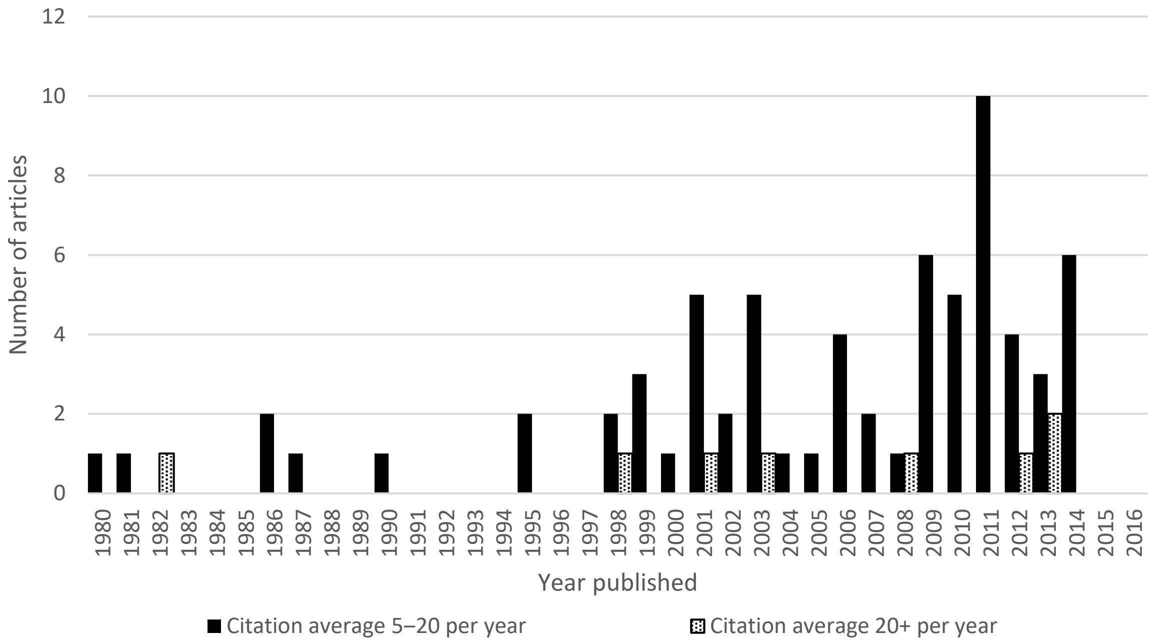


Figure 9.15: Distribution of South African water research articles with high average number of citations (1980–2016)

Source: Calculated from data obtained from Clarivate Analytics™ Web of Science™

It this section, it is evident that water research from South Africa has been cited consistently, with two thirds of publications being cited, and about half of these publications being cited on average around four times per year. Moreover, there are few publications that have recorded above average citations consistently, with an increase in these articles since the turn of the century along with an increase in research output, research impact and a stabilising research field. The citing of research is often associated with the journal in which researchers publish, which is investigated in the next section.

9.4 Distribution of South African research articles by journal

It is important for South African researchers to publish their research in accredited journals that adhere to rigorous peer reviewing (Bohannon, 2013; Gasparyan et al., 2015; Mouton & Valentine, 2017; Švab & Makivić, 2015; Weller, 2001). Moreover, publication and citation data of articles that are published in well-established journals, which adhere to principles of rigorous peer reviewing, are captured in citation databases. These citation databases present journal citation reports (JCR), and in the case of the Clarivate Analytics™ InCites™ JCR, citation data from approximately 12 000 journals and conference proceedings from over 3 000 publishers are analysed and presented in an online module (Clarivate Analytics, 2017). For the present study, citation data from water research publications between 1980 and 2016 were analysed to determine the top 10 journals (by total number of publications) in which researchers from

South Africa have published. The results are presented in Table 9.10. In addition, the ranking, which is calculated by a metric, which includes the journal impact factor (JIF) and total citations of the journals, are presented as obtained from the Clarivate Analytics™ InCites™ JCR.

It is evident that South African water researchers publish predominantly in *Water SA*, with almost 38% of publications being published by the South African Water Research Commission (WRC) (Table 9.10). The *Water SA* journal is not ranked as one of the top journals globally, and is ranked within the 3rd and 4th quartile of journals in recent years. Publications in *Water SA*, is followed by 14% of publications in *Water Science and Technology* (ranked 44th to 61st amongst journals between 2012 and 2016), *Physics and Chemistry of the Earth* (4,8% and journal ranked between 38th and 55th between 2012 and 2016) and *Water Research* (2,9%, and journal ranked as the top journal globally in recent years). From Table 9.10, it is further evident that amongst the top ten journals in which South African water research scientists publish articles, four journals have been ranked in the top 10 water research journals globally in recent years, and account for 8,21% of all South African research.

Table 9.10: Top 10 journals of South African Water research publications (1980–2016)

Rank	Journal titles	Number of publications	% of publications	Journal rank				
				2016	2015	2014	2013	2012
1	Water SA	1 771	37,96%	66/88	62/85	69/83	61/81	57/80
2	Water Science and Technology	644	13,80%	61/88	54/85	52/83	44/81	44/80
3	Physics and Chemistry of the Earth	223	4,78%	55/88	47/85	38/83	38/81	47/80
4	Water Research	136	2,91%	1/88	1/85	1/83	1/81	1/80
5	Desalination	103	2,21%	2/88	2/85	2/83	2/81	4/80
6	Journal of Hydrology	97	2,08%	6/88	6/85	7/83	10/81	5/80
7	Water, Air and Soil Pollution	65	1,39%	39/88	35/85	35/83	31/81	27/80
8	IAHS Publication	59	1,26%	Null	Null	Null	Null	Null
9	Hydrological Sciences Journal (Journal Des Sciences Hydrologiques)	55	1,18%	24/88	16/85	36/83	39/81	43/80
10	Aquatic Conservation Marine and Freshwater Ecosystems	47	1,01%	9/88	13/85	18/83	29/81	22/80
	Other journals	1 466	31,42%					

Source: Clarivate Analytics™ Web of Science™ and InCites™; Journal Citation Reports®

Based on the analysis of publication data, it is evident that South African researchers publish a large amount of water research in the local journal of the WRC, *Water SA*, with the three top-ranked journals accounting for 57% of all publications, and the top 10 journals accounting for 69% of all publications. Moreover, South African water researchers have published in some of the top-ranked water research journals globally, with four of the top 10 journals being ranked in the 1st quartile amongst journals. These journals are *Water Research*, *Desalination, Journal of Hydrology* and the journal *Aquatic Conservation Marine and Freshwater Ecosystems*.

When further assessing the journal publishing trends over time, as presented in Figure 9.16 and Figure 9.17, it becomes evident that there have been some instances where publications have increased over time, such as in the case of *Water SA* and *Physics and Chemistry of the Earth* (Figure 9.16) and the *Water, Air and Soil Pollution* (Figure 9.17). Note that, for clarity, the top 10 journals have been presented in two separate figures. In the case of the *Water Science and Technology*, there has been a steady decline in the publication of this journal over the years, from a high of 70 publications in 1982 to 15 publications in 2016.

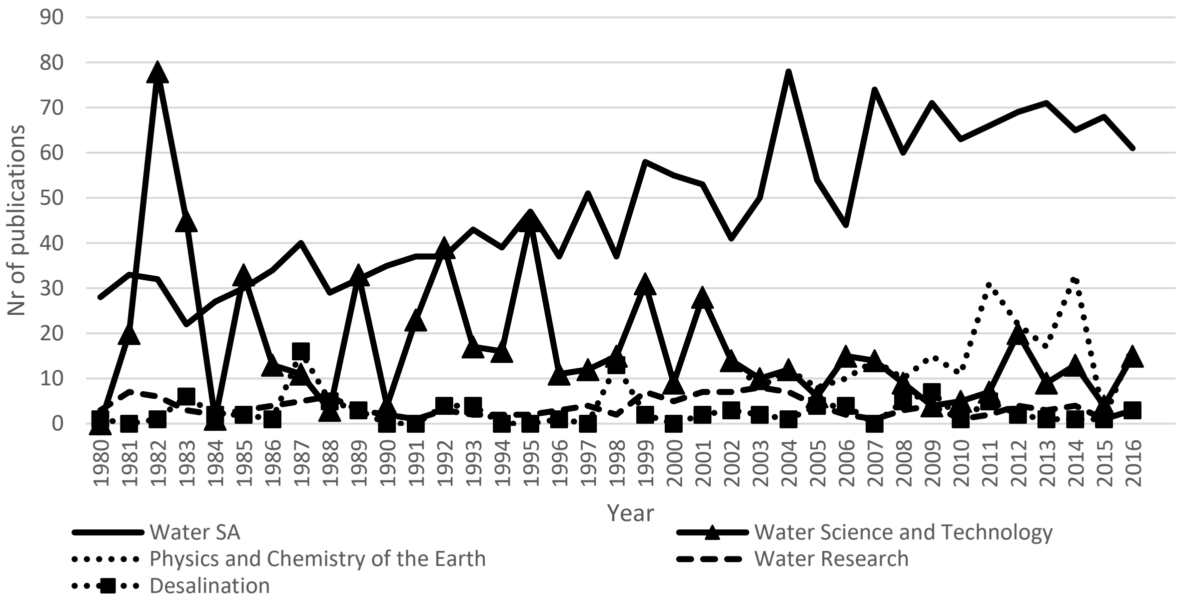


Figure 9.16: Annual distribution of South African water research publications between 1980 and 2016: Top 1–5 journals

Source: Clarivate Analytics™ Web of Science™

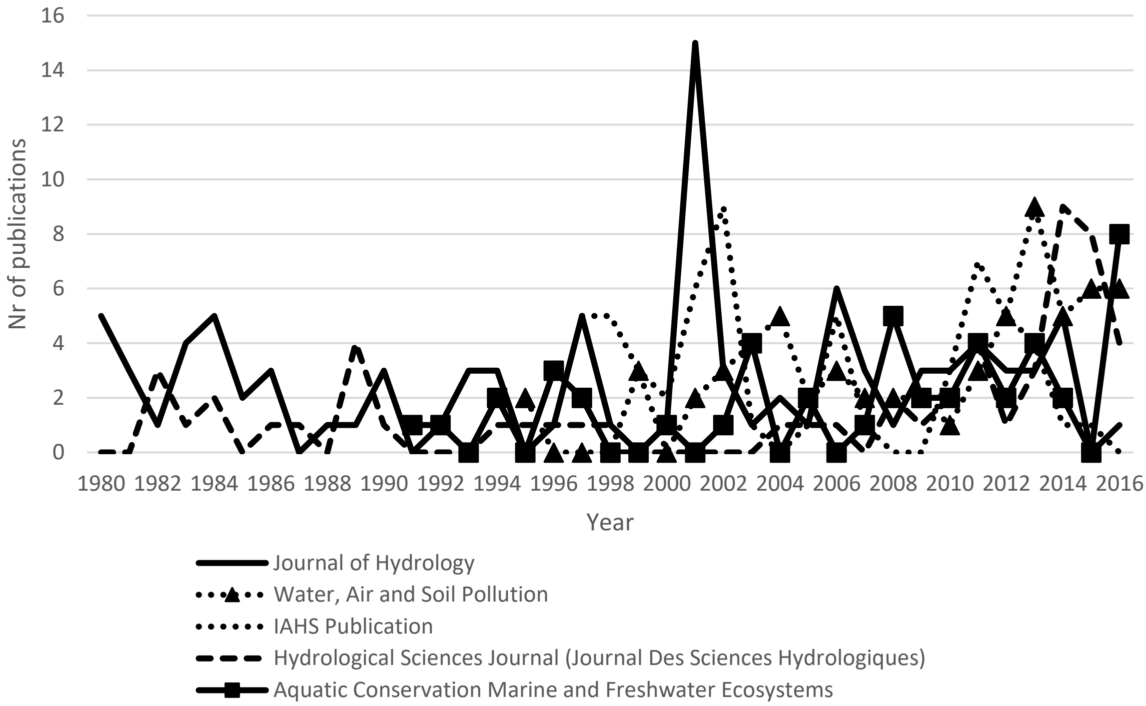


Figure 9.17: Annual distribution of South African water research publications between 1980 and 2016: Top 6–10 journals

Source: Clarivate Analytics™ Web of Science™

An interesting trend observed is the sporadic increases in the number of publications some journals have experienced in specific years. Journals such as *Physics and Chemistry of the Earth* (in 2007, 2011, 2014 and 2016), *Water Science and Technology* (several years between 1982 and 2016), *Agricultural Water Management* (1990 and 2011), the *IAHS Publication*[34] (2002, 2006 and 2011) and to an extent, *Water SA* (in 2004 and 2007).

As discussed in the previous chapter, it was evident that conferences can contribute significantly to the number of contributions in a journal in a specific year. In some cases, the contributions varied from 20% to 30% in the *Water SA* journal in 2004 and in 2015, and 68% of contributions in the journal *Water Science and Technology* in 1999, to name but a few examples. These high percentages of publications might have resulted due to the theme of the conference, where the theme of the conference was in line with specific fields published by a journal. In other cases, a conference organiser or sponsor could have had an agreement with a specific journal, who therefore published articles from the conference in a journal following the conference. It is for example known that contributions, which result from the annual WaterNet/WARFSA/GWP-SA symposium, are annually published in a special issue of the journal *Physics and Chemistry of the Earth*, resulting in 223 South African water research

[34] International Association of Hydrological Sciences

publications, or almost 5% of all water research publications since 2002, when this arrangement started.

The final section of this chapter focusses on the organisational support for water research in South Africa. In Chapter 6, the institutional landscape of the SADC water sector was presented, highlighting various institutions, and programmes, which play an important role in supporting water research. The following sections aim to provide some insight into the distribution of such support, and how such support translates into publication of water research.

9.5 Support for water research in the South African water sector

In the most recent report, the HSRC (2017b) calculated that South Africa's gross expenditure on research and experimental development (GERD) was ZAR 32.337 billion (or 0,80% of the GDP) for the 2015/2016 financial year. Given the multi- and interdisciplinary nature of water research, it is difficult to calculate the full extent of support provided to the South African water research accurately. Pouris (2015) suggests this amounted to ZAR 2.1 billion in 2014, with government and business being the major funders of the research in South Africa. In addition, Pouris (2015) suggests that around ZAR 240 million was spent on water-related R&D in 2014, up from around ZAR 50 million in 2000. The study further indicates that the WRC was funding 65% of all water-related R&D in South Africa in 2014, followed by the CSIR (16%), Mintek (9%) the National Research Foundation (NRF) with 8%, and the Agricultural Research Council (ARC), 2%.

Earlier in this study (see 6.5.1), the extent of the WRC's support in the most recent years was presented, and it is worthwhile to mention the main findings briefly here, to provide the necessary context to this section. Based on information obtained from the WRC's annual reports for the past seven years (WRC, 2010; 2011; 2012; 2013; 2014; 2015b; 2016), it is evident that, between 2009/2010 and 2015/2016, the WRC has supported 584 new projects and well over 3 000 students (of which 64% were from previously disadvantaged backgrounds). During the same period, expenditure in research (excluding research dissemination) amounted to ZAR 876.79 million, at an average amount of ZAR 125.26 million per year. The support from the WRC not only results in a significant portion of South African water research being published in *Water SA*, as was evident in the previous section, but a number of contributions also appear in *WaterWheel,* which is read by a diverse range of readers such as schoolteachers, farmers, environmental groups and policymakers. In addition, the WRC supports a number of technical and policy notes, ministerial briefs, manuals, guidelines and events. For full details on the support of the WRC over the past few years, see section 6.5.1.

However, even though the WRC is evidently a major contributor of water research and capacity development in South Africa, there are various other role players. As in the previous chapter, one source could be the acknowledgments researchers provide to funding sources when publishing research, which is then captured in citation databases. There are however limitations in the use of the data, in that the Clarivate Analytics™ Web of Science™ has only been capturing information on funding sources actively since 2008, and different spelling versions exist for the same funding source. Moreover, researchers do not always acknowledge the funding agencies when publishing an article, unless it is explicitly required as part of a funding agreement. However, this data provide some insight into the organisations who provide support for South African water research.

An analysis of the 4 666 water research articles published in South Africa between 1980 and 2016, revealed that acknowledgement data were not available for 78,54% of the publications. The available funding agency data were indeed limited to after 2007. For this reason, funding agency data were restricted to water research publications between 2008 and 2016, which resulted in the analysis of 1 978 publications. For these publications, 1 928 funding agency records were extracted and categorised according to the following categories:

- Type of funding agency:
  a. research funding agency, such as the NRF, the WRC, or the Swedish Sida;
  b. university or research institute, typically based at a university;
  c. a government department;
  d. private industry;
  e. other – a small percentage of institutions could not be categorised, and were therefore named ‘other’, as insufficient information is available on the records.

- Geographical location:
  c. Locally within the SADC region: research funding agencies, universities/research institutes, government ministries and departments and private industry. In addition, in order to provide a better indication of South African support versus the rest of the SADC region, data for the local research funding agencies and university/research Institutes were further divided indicating the portion of South African agencies and universities/research institutions versus the rest of SADC.
  d. International research funding agencies, universities/research institutes and government ministries and departments.

Results of the categorisation are presented in Table 9.11 and Figure 9.18.

Table 9.11: South Africa water research funding institutions (2008–2016)

Type of funding organisation	Geographical location	Count	% of total acknowledgements
Research funding agency	Local	790	40,0%
Research funding agency	*South Africa*	758 (of 1 973)	38,4%
	Rest of SADC countries	32 (of 1 973)	1,6%
Research funding agency	International	318	16,1%
University/Research institute	Local	348	17,6%
University/Research institute	*South Africa*	337 (of 1 973)	17,1%
	Rest of SADC countries	11 (of 1 973)	0,6%
University/Research institute	International	94	4,8%
Government	Local	140	7,1%
Government	International	74	3,8%
Private industry	Local	100	5,1%
Private industry	International	45	2,3%
Other		64	3,2%
TOTAL		**1 973**	**100%**

Note: Funding agency records were limited to between 2008 and 2016, as Clarivate Analytics™ Web of Science™ only started capturing such data actively in 2008.

Source: Clarivate Analytics™ Web of Science™

From Table 9.11 and Figure 9.18, it is evident that local research funding mechanisms were acknowledged in 70% of cases when researchers published contributions on water research in South African, and international funding mechanisms acknowledged 37%. **Local funding mechanisms** are divided into 40% support through research funding agencies (which is the most prevalent), with South African research funding agencies acknowledged 38,4% of the time for support, and other research funding agencies in the SADC region, acknowledged 1,6% of the time. Given the limitation that different spelling versions exist for the same institution, it is not possible to provide accurate figures for specific institutions. However, a brief calculation indicated the WRC and the SA NRF, accounted for no less than 18% of the acknowledgements respectively. In addition to South Africa research funding agencies, universities and research institutions in South Africa recorded 17,6% of acknowledgements, with South African universities and research institutions having been acknowledged 17% as funding agency for research in South Africa, and other universities and research institutions from the other SADC countries, less than 1%. South African government institutions and private industry recorded 7% and 5,1% of acknowledgements (Figure 9.18). **International funding mechanisms** are divided into 16% of the acknowledgements attributed to international research funding agencies such as the Canadian Natural Sciences and Engineering Research Council (NSERC) and the European Research Council, international universities and research institutions recording 4,8%, international governments 3,8% and international private industry 2,3%. It is evident that between the local and international funding, the ratios between research funding agencies, universities/research institutions, governments and private industry are more or less the same.

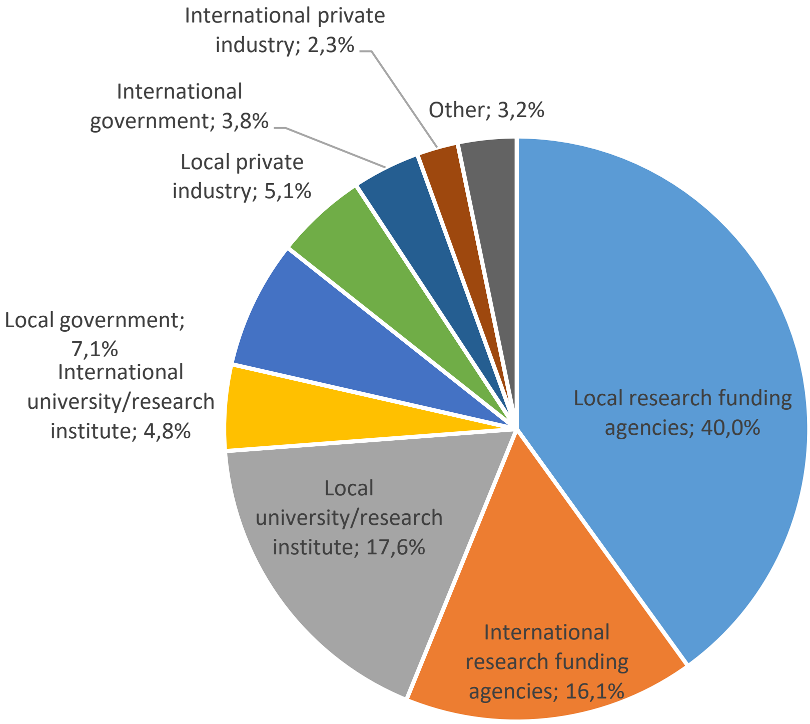


Figure 9.18: South African versus international funding mechanisms for South African water research (2008–2016)

Source: Clarivate Analytics™ Web of Science™

From the analysis, it is clear that universities and research institutions from beyond the SADC are acknowledged more than SADC universities as funding agencies, at almost 5% of acknowledgements versus 1,6%. This is to be expected since South African universities tend to co-author publications more with universities and research institutions beyond the SADC, than in the SADC region, as was established earlier in this chapter (see 9.2.2.2).

Finally, when one considers the acknowledgements attributed to private industries in South Africa, which comprise 5,1% and 2,3% by international industry, such figures would not necessarily be accurate. The reason for this is that, since these acknowledgements represent research undertaken and reported in peer-reviewed journals, one would suspect that the contribution from private industry would actually be higher, as their research would translate into patents with an economic potential, rather than peer-reviewed articles.

9.6 Summary and conclusion

In this chapter of the study, various aspects relating to water research in the South Africa were analysed, based on bibliometric data for the period 1980 to 2016. Given that previous bibliometric studies have been conducted on this topic in South Africa, often with slightly different timeframes, there will inevitably be some level of overlap in the findings.

In this chapter, it was reported that South Africa has a diverse research focus, with the top research areas namely Engineering, Medicine, Chemistry, Environmental Sciences, Physics, related topics in Science and Technology, Plant Sciences, Zoology, Agriculture and Mathematics. Within these research focus areas, South African water research is placed relatively high, and ranked 26th out of 151 research areas in the country. Moreover, even though water research output from South African universities and research institutions is increasing, it is more or less at the same rate as the global rate for water research, and there is a rise in water research from other African countries. In addition, there are few researchers in South Africa who are responsible for a proportionally large percentage of water research publications, with strong research networks developed around them over the years. These researchers include Prof. Ekama and Prof. Wentzel (UCT), Prof. Buckley (UKZN), Prof. Hughes (RU), Prof. Mamba (UJ) and Prof. Grabow and Prof. Cloete when the latter was still at UP. In terms of the links of researchers with the WARFSA-programme, it is evident that few of the top researchers can be associated with any publication emanating from the WARFSA-programme.

It is further evident that water research in South Africa mainly focusses on keywords such as water management in South Africa, with links to research fields such as performance monitoring, modelling of water resources, climate change and catchment management. In addition, prominent clusters are evident with keywords such as the removal and ‘heavy metals’ and ‘drinking water’ and ‘groundwater’. Previous research had suggested that before 1991, the research focus was on the hydraulic mission of South Africa, with many engineering and laboratory-related research undertaken. After 1991, water research in South Africa focussed increasingly towards management and planning of water resources.

In terms of the number of publications water researchers have produced, it is evident that 67,3% of authors have published one publication, and 15,2%, 5,6% and 3,2% have published two, three and four publications respectively. The significant difference between a single contributions and multiple contributions was evident.

Over the years, single-authored publications have declined, with the majority of contributions having two or more authors, with contributions with more than three co-authors the most prevalent in recent years, comprising 75% of all publications in 2016. During the same period, contributions with more than five authors have further experienced significant increases, comprising 24% of publications. These co-authored contributions have further been predominantly with countries beyond the SADC, with the most notable countries being the United States, the United Kingdom (England), Australia and the Netherlands. To a lesser extend co-authored contributions were within the SADC region, with the dominant countries for water research co-publications being Zimbabwe, Botswana, Namibia, Tanzania and Malawi, with significant increases recorded in research output since the turn of the century. There are furthermore countries such as France, in the Global North, which appear regularly amongst the top five countries with which South African water researchers have co-authored contributions in recent years. Moreover, countries such as India and the People's Republic of China have emerged as countries in the Global South, and Nigeria and Kenya on the African continent as those with which South African water researchers tend to co-author contributions on a regular basis, in most recent years.

In terms of the citation trends of South African water research, 25% of water research published by South African institutions has never been cited, which is normal, as not all publications are always cited. It is further evident that just over half of all publications (52%) have been cited between one and ten times, at an average citation rate of 4,11 per article. There are a further 37 publications, which received more than 100 citations each. These publications account for only 0,79% of all publications, and received 18,2% of all citations, and will be investigated further in this section.

It is evident that the annual number of publications has gradually increased over the years, from 46 in 1980 to a point in 2001 where the number of publications increased to above 150 for the first time. These publications were increasingly cited, along with the gradual increase in publications. After 2001, the total number of water research publications declined slightly to 112 publications in 2005, after which it gradually increased to 268 publications in 2016. During this time, after the turn of the century, the average annual citation rate remained constant between 1,49 in 2003 and 8,89 (in 2006), and only continuously declining since 2013 – this can be attributed to the time lag it takes between the publication of articles, and the citation of these articles.

Based on the calculation of the mean normalised citation score (MNCS) of South African water research publications were well above 1 in the early 1980s - a MNCS-value of 1 means that the citation impact of a specific set of publications are generating citation rates equal to the world average for publications in that field. Since then, these values steadily declined. As a result, even though the volume water research articles produced by South African water researchers has increased steadily over the years, the citation impact has declined especially since the turn of the century. This, unfortunately, means that the increased production has not occurred with a commensurate increase in visibility.

South African water researchers further publish 38% of articles in the South African WRC's scientific journal *Water SA*. In addition, 8,21% of South African water research is published in journals that are ranked amongst the top ten globally. These journals are *Water Research*, *Desalination, Journal of Hydrology* and *Aquatic Conservation Marine and Freshwater Ecosystems*. Over time, South African publications in the some journals, such as *Water SA*, *Physics and Chemistry of the Earth, Water Air and Soil Pollution* have increased, while there was a decline in others, such as *Water Science and Technology*. However, the most evident observation is the sporadic increases of articles in some journals in specific years. This is often due to the contribution by a specific conference towards research output, where the theme of the conference is in line with specific fields published by a journal, or in other cases where a conference organiser or sponsor has an agreement with a specific journal and therefore publishes articles from the conference in a journal following the conference. An example is the annual WaterNet/WARFSA/GWP-SA symposium, where a special issue of the journal *Physics and Chemistry of the Earth* is published following the symposium. This arrangement has directly and indirectly resulted in 223 contributions from South African water researchers, or almost 5% of all water research articles, published in the journal *Physics and Chemistry of the Earth* since 2002.

Finally, in terms of the institutional support for water research in South Africa, it is evident that the WRC and the NRF are the most significant supporters of research, as local research funding agencies are acknowledged by 40% as funding agency in publications since 2008 when data was captured in the Clarivate Analytics™ Web of Science™. In the case of the WRC and NRF, these institutions are acknowledged by no less than 18% of contributors. This is followed by South African universities and research institutions in South Africa (17,6%), international funding agencies (16,1%) and South African government departments (7,1%). South African private industries and international universities/research institutions are further acknowledged by 5,1% and 4,8% respectively, with international governments and private industry acknowledged to a lesser extent.

With the South African water sector dominating the SADC region in terms of research output, our attention now shifts towards the other SADC countries, where South African water research output is excluded, with the objective to determine specific publication and citation trends from these countries. For the purpose of this study, these countries are collectively referred to as the SADC-ExSA countries, and are Zimbabwe, Tanzania, Botswana, Malawi, Namibia, Zambia, Mozambique, Swaziland, Mauritius, the Democratic Republic of Congo, Lesotho, Madagascar, Seychelles and Angola.

In this chapter, various aspects relating to water research in South Africa were discussed, with the next chapter focusing on research outputs, authorship and citation trends, scientific journal distribution of articles, and support for the research in the SADC-ExSA countries.

Chapter 10

PUBLICATIONS IN THE REST OF SADC (EXCLUDING SOUTH AFRICA)

10.1 Introduction

As was evident in previous chapters of this thesis, water research output in the SADC region is dominated by articles from researchers affiliated to South African universities and research institutions. Moreover, even though there has been an increase in the in-country effort in many SADC countries, especially since the turn of the century, SADC countries beyond South Africa (further referred to as 'SADC-ExSA countries'), have only produced 26% of all water research between 1980 and 2016. By comparison, South African water researchers have produced 81%. For this reason, a bibliometric analysis of research in the SADC-ExSA countries is discussed in this chapter.

At this stage, it is pertinent to acknowledge other bibliometric studies. In a recent study, Wambu and Ho (2016) undertook a bibliometric analysis of drinking water research in Africa in articles between 1991 and 2013 (see section 3.2 for major findings of the study). When it comes to bibliometric studies in the SADC region, it is evident that few bibliometric studies have been undertaken in the SADC water sector. Previous studies mainly focussed on South Africa (Jacobs, Pouris et al., 2014; Pouris, 2013; 2015; Siebrits & Winter, 2013; Siebrits, Winter, Barnes et al., 2014; Siebrits, Winter & Jacobs, 2014), with the only other known SADC-wide study undertaken by Van der Zaag (2007). In his study, Van der Zaag assessed the qualitative and quantitative contribution of the WaterNet/WARFSA/GWP SA symposium papers, and how the WaterNet/WARFSA/GWP SA symposium papers translate into articles published in five special issues (2002–2006) of the scientific journal, *Physics and Chemistry of the Earth (PCE)*, which was linked to the symposium. Van der Zaag addressed topics such as the number of symposium papers and posters, in comparison with the number of articles in the special issues of the journal *PCE* and the themes covered by the articles in the special issues. In addition, Van der Zaag argued that the symposium has made a contribution in water research on the continent, not just in terms of the quantity of articles, but also in terms of the quality of articles, as there was an increase in the citation index, specifically in the journal *PCE*. Finally, Van der Zaag analysed the citations of articles published in the five special issues of the journal *PCE* for the period 2002 to 2006, and further how citations translated into the five thematic areas of the symposium (for more detail on the major findings of the study, refer to section 3.2.1).

Naturally, there are also other bibliometric studies which provide broad insight into science production on the African continent (Adams et al., 2010; Narváez-Berthelemot et al., 2002; NEPAD, 2010, 2014; UNESCO, 2015; World Bank Group, 2014), or which focus on a specific topic such as research collaboration (Adams et al., 2014; Confraria & Godinho, 2014; Onyancha & Maluleka, 2011; Pouris & Ho, 2013; Pouris & Pouris, 2009; Toivanen & Ponomariov, 2011). Moreover, some studies focus on other regions, such as the Arab countries (Waast & Rossi, 2010), West Africa (Mêgnigbêto, 2013a; 2013b; Owusu-Nimo & Boshoff, 2017), Central Africa (Boshoff, 2009) and Southern and South Africa (Boshoff, 2010; Mouton et al., 2008; Pouris, 2010; 2017; Sooryamoorthy, 2009), and provide insight into specific research areas, which are researched in the African regions.

When it comes to water research in the SADC region, most previous studies and articles predominantly focussed on South Africa (Jacobs, Du Plessis et al., 2014; Jacobs, Pouris et al., 2014; Pouris, 2013; 2015; Siebrits & Winter, 2013; Siebrits, Winter, Barnes et al., 2014; Siebrits, Winter & Jacobs, 2014).

There are thus many unanswered questions relating to water research articles within SADC-ExSA countries, with this chapter systematically analysing the research output, authorship and collaboration trends, citation analysis, the journal distribution and institutional support for water research from SADC-ExSA countries between 1980 and 2016.

10.2 Research output from SADC-ExSA countries

In this section of the chapter, a general overview of water research output from SADC-EXSA countries is presented, and will include an analysis of authorship and co-publishing trends, to identify who the prolific authors were, and further with which countries co-articles took place during the study period (1980–2016). For detail on the methodology used to extract bibliometric data, see section 5.3.1.

Based on the bibliometric analysis of article and citation data, it is evident that during the study period, 1 217 water research articles were produced by researchers from SADC-ExSA countries,[35] with highs of 96 articles annually resulting in 2014 and 2016 (Figure 10.1). Here it further becomes evident that very few water research articles were produced in the 1980s, with fewer than 10 articles produced annually (Figure 10.1). This period is followed by a general increase of more than 10 articles annually, with three significant periods of increase: the first in 1990, the second more prolonged between 2002 and 2006, and the last between 2014 and 2016. At the same time, it is evident that even though few articles were produced in the 1980s, articles produced in 1986, on average, had a relatively high number of citations (Figure 10.1). Moreover, since the increase in articles from the early 1990s, the average number of citations of articles increased again, to the early 2000s, after which the average number of citations declined. This can be attributed to the dramatic increase in the number of articles produced during this time, and due to the time lag between when articles were published to when they

[35] In extracting water research articles from the Clarivate Analytics™ Web of Science™ Core collection database, “ALL DOCUMENTS” and “ALL DOCUMENT TYPES” were selected.

were cited, especially for the most recent articles. The citation analysis of articles is analysed in more detail later in this chapter (see 10.3).

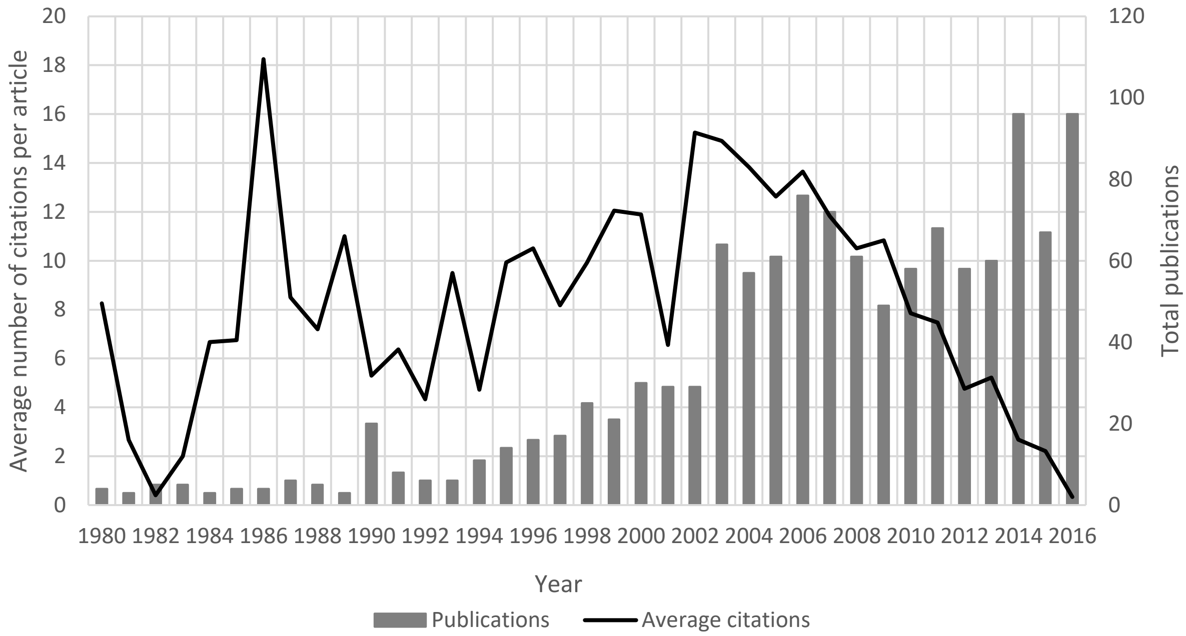


Figure 10.1: Water research articles in SADC-ExSA (1980–2016)

Source: Clarivate Analytics™ Web of Science™

One however needs to compare the SADC-ExSA research output with other research output, at least on the African continent, with Figure 10.2 providing the annual distribution of SADC-ExSA countries' share of African water research output, along with South Africa's share of African water research output. Given the relatively low research output of SADC-ExSA countries, a comparison with the world share is not provided. As established in the previous chapter (see section 9.2), even though South African water research output has increased in recent years, South Africa's share of African research output has declined over the years, suggesting an increase in the research output from other African countries.

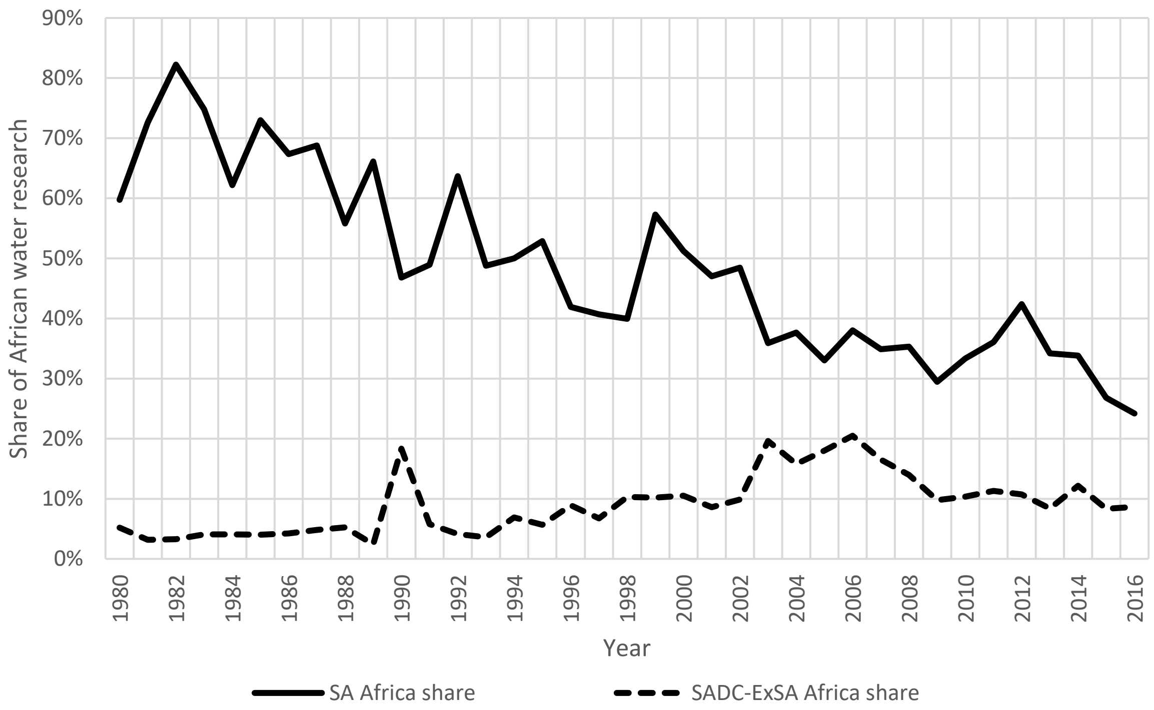


Figure 10.2: SADC-ExSA and South African share of African water research articles (1980–2016)

Source: Clarivate Analytics™ Web of Science™

In the case of SADC-ExSA countries, there has been a general increase in the SADC-ExSA share of African research, albeit marginal, since the early 1980s to the end of the 1990s, after which it stabilised at around 10% (Figure 10.2). As further evident in Figure 10.2, this trend was interrupted by two significant increases.

The first increase occurred between 1989 and 1992 when the water research output of SADC-ExSA suddenly peaked at 18% of Africa's share of water research articles in 1990 and declining again to 3,6% in 1993. An assessment of the SADC-ExSA data revealed that 17 out of the 20 articles published in 1990, appeared in the journal *Agricultural Water Management,* which was also linked to the Symposium on the Irrigation of Sugarcane and Associated Crops, which took place in Mauritius in 1988. This phenomenon highlights the outcome of publishing conference proceedings in a special issue of a journal, as also found by Van der Zaag (2007). Such influences on the annual research outputs, which followed conferences, were also observed in Chapter 8, where it became evident that amongst journals in which South African water researchers publish, conferences can often contribute between 20% and 68% of annual research output in a journal (see 8.5).

The second, more prolonged, increase occurred between 2002 and 2006, when the share of African research from SADC-ExSA countries dramatically increased to a high of 20,5% in 2006 (from 10% in 2002), as evident in Figure 10.2. This period was followed by a general decline to around 10% in recent years (Figure 10.2). A reason for this specific increase in research output in the SADC-ExSA countries could be the implementation of the Water Research Fund for Southern Africa (WARFSA), which was implemented in two phases between 1999 and mid-2005. This is further evident by the high number of articles in the journal *Physics and Chemistry of the Earth* and conference proceedings from the annual WaterNet/WARFSA/GWP SA symposium, which were both associated with the WARFSA programme, as presented by Van der Zaag (2007). This event will however be investigated in more detail in Chapter 11, of this thesis (see section 11.4.1).

It is thus evident that along with a gradual increase in water research output over the years, SADC-ExSA countries have increasingly contributed to the share of African water research, in terms of research publication, with the total research output per country for all SADC-ExSA countries presented in Figure 10.3. Here it becomes evident that countries such as Zimbabwe, Tanzania, Botswana, Malawi and Namibia are among the top countries in terms of research publication. Incidentally, these are countries that have all recorded an increase above the average effort SADC countries devote to water research, since the turn of the century, as indicated earlier in this thesis (see section 7.2.2). Moreover, these countries are the top countries with which South African water researchers co-author articles within the SADC region, as also indicated earlier in this study (see section 9.2.2). Other countries that have consistently published water research over the years are Zambia, Mozambique, Mauritius, Swaziland and Lesotho. This is significant, given the research capacity and infrastructure in South African universities and research institutions, contributing towards resources for research.

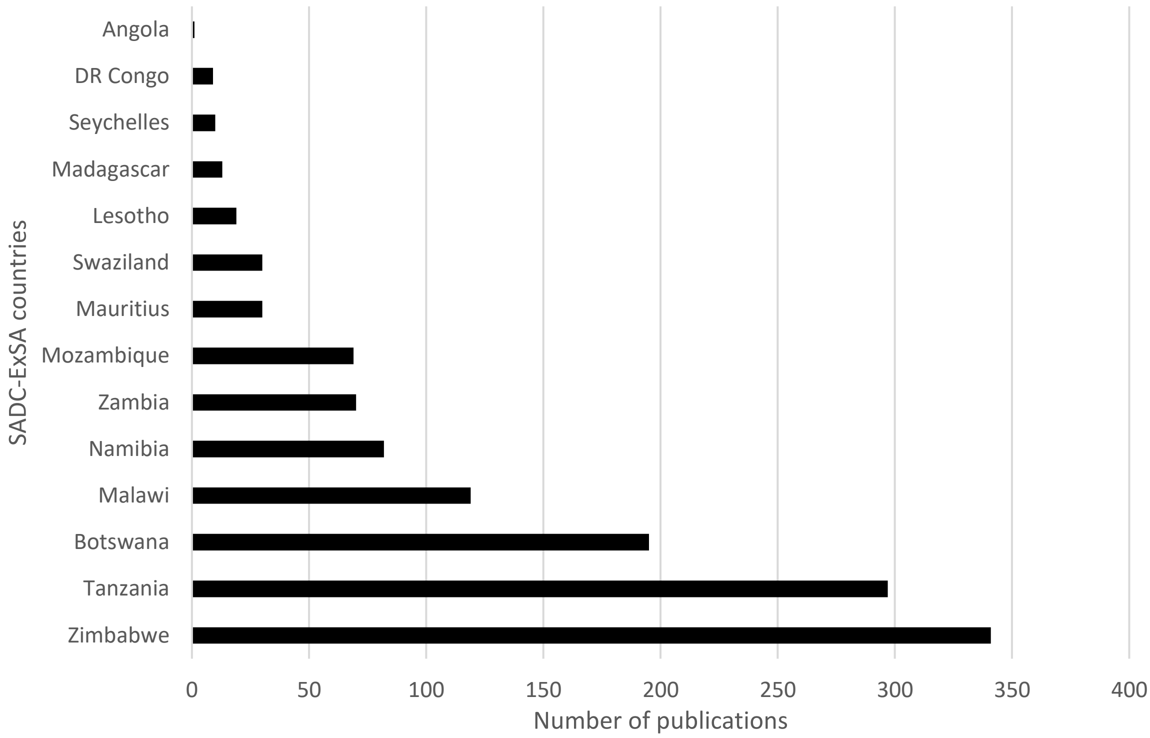


Figure 10.3: Total water research articles per SADC-ExSA country (1980–2016)

Source: Clarivate Analytics™ Web of Science™

The annual distribution of water research output of the top five SADC-ExSA countries is presented in Figure 10.4, where it is evident that around the early to mid-1990s, increases in water research output were recorded. The most significant increases however occurred around the turn of the century, especially from research institutions in Zimbabwe and Tanzania, with increases following by research institutions in Botswana in the mid-2000s. In the case of Botswana, research output declined again from the mid-2000s, after which it stabilised. Research output from Malawian universities and research institutions steadily increased from the mid-2000s to the third most in 2016, with Namibia increasing water research output from around 2010. Again, much of these increases coincided with the implementation of the WARFSA programme in the region, along with the annual WaterNet/WARFSA/GWP SA symposium.

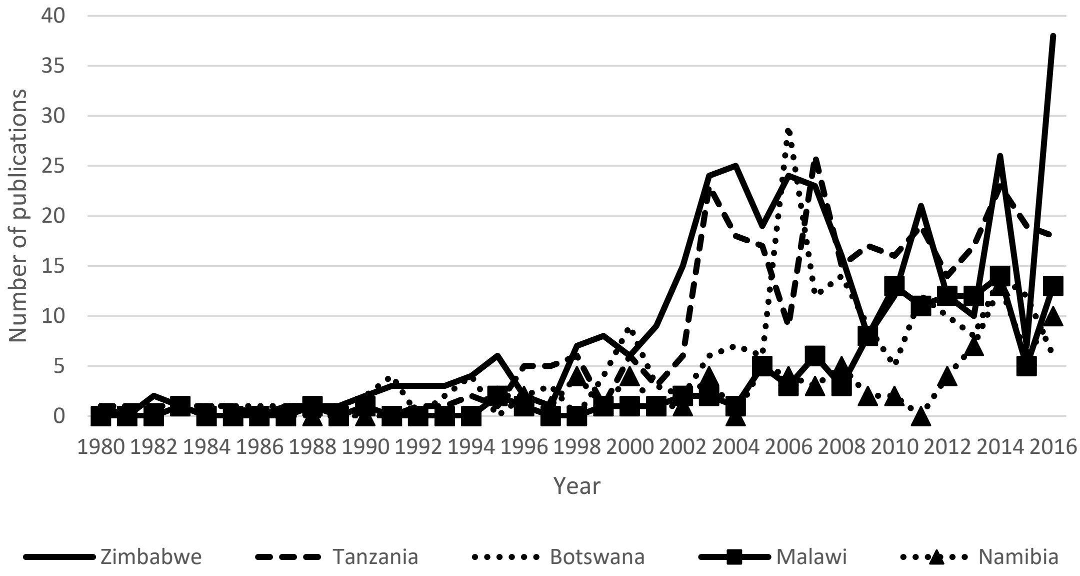


Figure 10.4: Water research output of top five SADC-ExSA countries (1980–2016)

Source: Clarivate Analytics™ Web of Science™

From the chapter thus far, it is evident that water research in SADC-ExSA countries has increased significantly since the turn of the century. In order to provide a better understanding of the focus areas of research undertaken during this time, an analysis of the co-occurrence of keywords[36] from articles was analysed, making use of VOSViewer® software. In total, 1 851 keywords were identified and, after setting the minimum occurrence of keywords to a threshold of five, 140 keywords met this criterion. The results of the scientometric map representing the density visualisation analysis, are presented in Figure 10.5. Here, more prominent keywords are presented as clusters with warmer colours thus presenting clusters of greater prominence, and colour contours showing how strongly related the keyword clusters are. From Figure 10.5, it is thus evident that water research in SADC-ExSA countries predominantly focussed on the **modelling** of **water systems**, and the **management** aspects with keywords including **conservation**, **Southern Africa**, **Africa**, **climate change**, **rainfall**, **systems**, **Zimbabwe** and **river-basin**. Other predominant research areas include **river systems**, **groundwater quality**, **climate** with links to **variability**, **rainfall** and **impact**.

[36] KeywordPlus words was used in the analysis

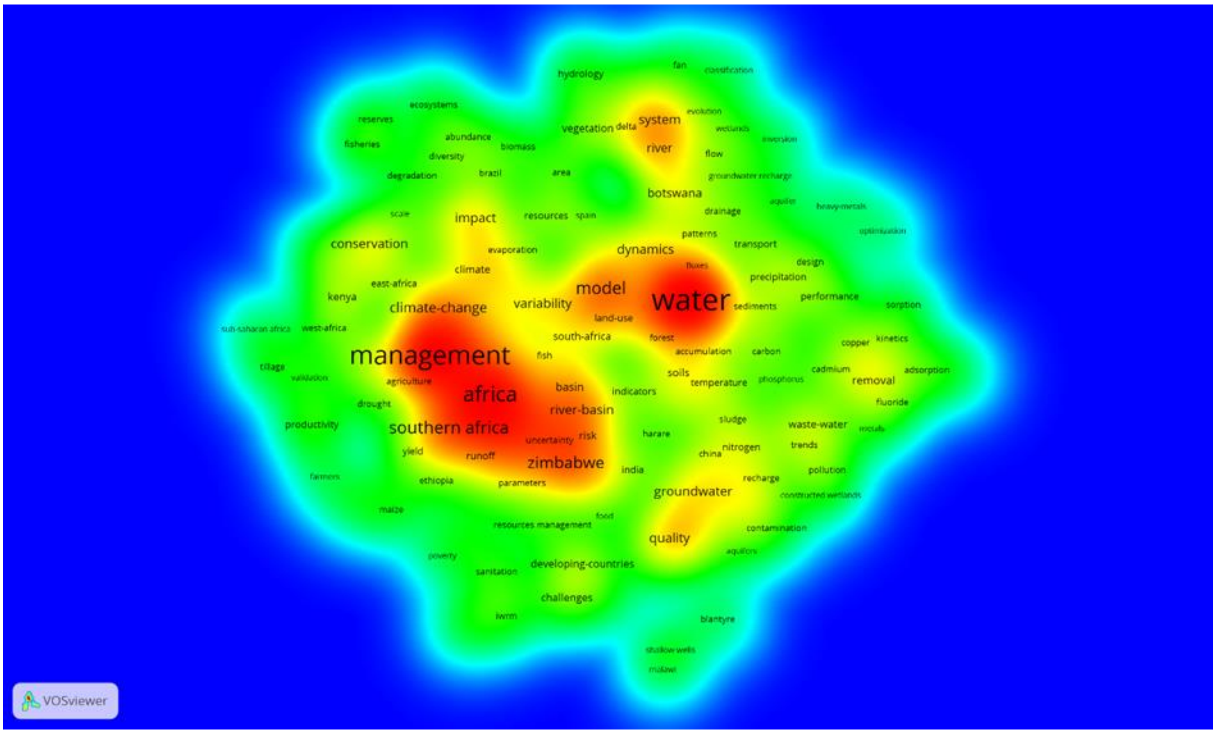


Figure 10.5: Density visualisation of Keyword Plus words of water research in SADC-ExSA countries (1980–2016)

Source: Clarivate Analytics™ Web of Science™

Our focus now moves towards the authorship characteristics of the water research emanating from SADC-ExSA countries, with section 10.2.1 elaborating on the co-article trends in terms of the number of authors per article, who the prolific authors were and from which countries or institutions they were. In addition, research networks and countries, with which SADC-ExSA water researchers tend to co-publish, are discussed.

10.2.1 Authorship of SADC-ExSA water research

Bibliometric analysis of article data indicates that between 1980 and 2016, 2 699 researchers contributed towards the 1 217 water research articles where there were at least one author from an SADC-ExSA country. This roughly translates into 2,2 authors per article. However, following Alfred Lodka's observations (Lotka, 1926), only few researchers often contribute towards the bulk of research outputs. An analysis of the percentage distribution of SADC-ExSA water researchers who have published between one and eleven (and more) articles each, is presented in Figure 10.6. Here it becomes evident that 77% of all researchers have published one article, accounting for 2 086 authors. The number of authors who have published two articles declines to 12% (or 333 authors), followed by less than 5% or 117 authors, publishing three articles. On the other end of the scale, there are 24 authors, who have published more than 10 articles. It is further worthwhile to discuss the article detail of these researchers, as they have been responsible for 17% of all water research in the SADC-ExSA countries. For the purpose of this study, they are referred to as the 'prolific researchers', with additional article and citation data presented in Table 10.1.

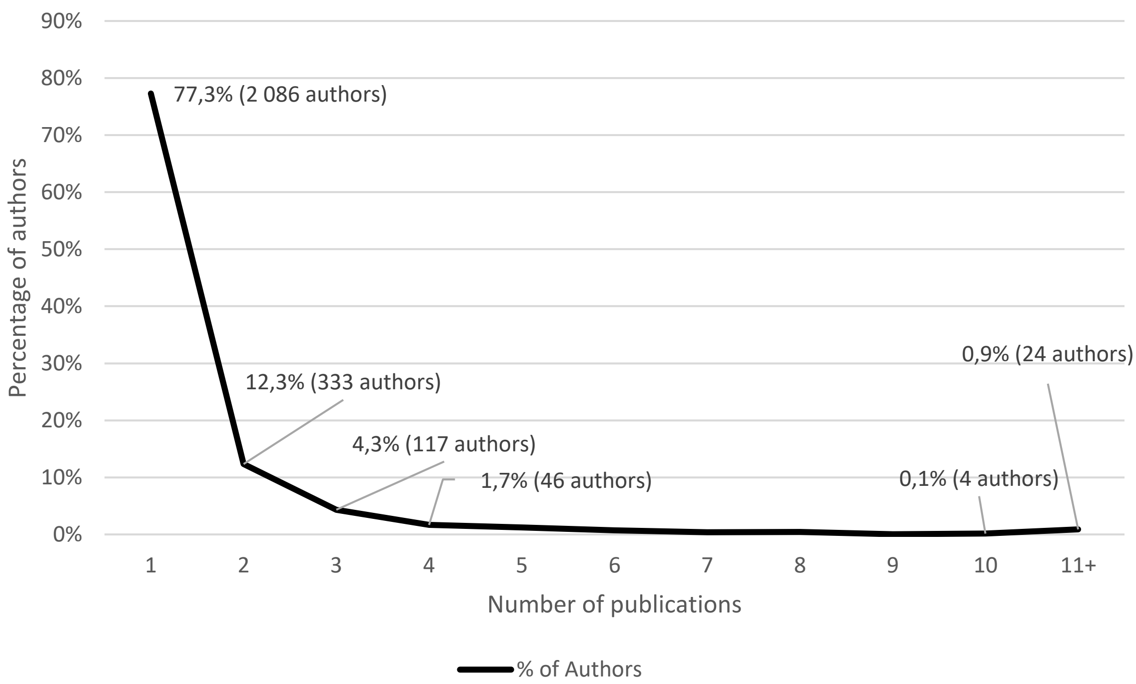


Figure 10.6: Distribution of SADC-ExSA water research publications by number of articles between 1980 and 2016

Source: Clarivate Analytics™ Web of Science™

In Table 10.1, article and citation data of water researchers who have published more than 10 articles in collaboration with SADC-ExSA countries are presented, with data such as the number of articles per author (also presented as a percentage of the total number of articles), the average citations per item, and the *h*-index[37] of the author for the articles in this research field. In addition, the number of times articles have been cited, the number of self-citing from articles (further presented as a percentage of articles), the institution and country of the researcher are presented, and finally, if the researchers can be associated with a WARFSA publication. In terms of research output, Prof. Innocent Nhapi from UZ (now from Chinhoyi University of Technology in Zimbabwe), has produced the most water research articles in the SADC-ExSA countries, followed by Prof. Pieter van der Zaag from the Delft University of Technology (Delft–UT) in the Netherlands. Although the Delft–UT is not in one of the SADC-ExSA countries, the article output of Prof. Van der Zaag would indicate co-publication with researchers in SADC-ExSA countries. These researchers are followed by Dr David Love (then

[37] Refer section 5.3.2.1 for a more detailed explanation of the *h*-index.

at WaterNet and at the UZ), followed by Prof. Henry Mahoo from Sokoine University of Agriculture (SUA) (Tanzania), Dr Hodson Makurira and Dr Zvikomborero Hoko, both from UZ. These researchers have all published more than 20 water research articles. Other researchers from various universities and research institutions in the SADC-ExSA countries are amongst the researchers who have published more than 10 articles. These institutions are the University of Botswana (UB) (Botswana), University of Dar es Salaam (UDSM) (Tanzania), Eduardo Mondlane University (UEM) (Mozambique), the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) (Zimbabwe), the Polytechnic Namibia (now known as the Namibia University of Science and Technology [NUST]), and University of Malawi (UNIMA) (Malawi). There are further universities and research institutions beyond the SADC-ExSA countries apart from the Delft–UT mentioned earlier, such as UCT, UWC, Wits, UKZN – all from South Africa. An addition, where multiple institutions are associated with researchers, this would indicate that these researchers have moved to various institutions over the years, and have continued publishing articles with the institutions. With long-standing support of the UNESCO IHE for WaterNet (a regional capacity development programme, which is discussed in section 6.3.1) and the WaterNet/WARFSA/GWP SA symposium, the significant collaborations are evident by the high number of researchers from the Delft–UT in the list of most prolific researchers in the SADC-ExSA countries.

Table 10.1: Researchers who have published more than 20 water research articles in SADC-ExSA countries (1980–2016)

Rank	Authors	Articles	% of 2 699 articles	Average citations per item	Times cited	Self-citations	Self-citations as % of articles	*h*-index	Organisation	Country	WARFSA publication association
1	NHAPI I	32	2,6%	5,19	166	14	8,4%	7	UZ, CUT	Zimbabwe	Yes
2	VAN DER ZAAG P	26	2,1%	10,65	277	20	7,2%	13	WaterNet, Delft–UT	Netherlands	No
3	LOVE D	24	2,0%	16,63	399	39	9,8%	13	WaterNet, UZ	Zimbabwe	Yes
4	MAHOO HF	23	1,9%	13,17	303	9	3,0%	9	SUA	Zimbabwe	Yes
5	MAKURIRA H	22	1,8%	8,36	184	17	9,2%	10	UZ	Zimbabwe	No
6	HOKO Z	21	1,7%	11,57	243	16	6,6%	9	UZ	Zimbabwe	Yes
	Sub-total (20+ articles)	148	5,5%		1 572	115					
	Average (20+ articles)			10,93	262	19,16		10,17			
7	MANZUNGU E	20	1,6%	5,10	102	11	10,8%	6	UZ	Zimbabwe	Yes
8	WOLSKI P	20	1,6%	23,50	470	27	5,7%	10	UB, UCT	Botswana	Yes
9	MAZVIMAVI D	20	1,6%	14,00	280	6	2,1%	8	UZ, UWC, UB	Zimbabwe, SA, Botswana	Yes
10	SENZANJE A	18	1,5%	11,28	203	10	4,9%	9	UZ, UKZN	Zimbabwe, SA	Yes
11	SAVENIJE HHG	18	1,5%	21,56	388	19	4,9%	13	Delft–UT	Netherlands	Yes
12	MUL ML	17	1,4%	9,82	167	9	5,4%	10	UZ, Delft–UT	Zimbabwe	Yes
13	MAYO AW	16	1,3%	15,53	233	14	6,0%	8	UDSM	Tanzania	No
14	MASHAURI DA	16	1,3%	8,44	135	2	1,5%	7	UDSM, Polytech Namibia	Tanzania, Botswana, Namibia	Yes
15	UHLENBROOK S	15	1,2%	14,87	223	16	7,2%	11	Delft–UT	Netherlands	No
16	OWEN R	15	1,2%	6,40	64	3	4,7%	6	UZ	Zimbabwe	Yes
17	MURRAY-HUDSON M	14	1,2%	12,14	170	9	5,3%	7	UB, UCT	Botswana	No
18	JUIZO D	13	1,1%	9,77	127	10	7,9%	7	UEM	Mozambique	No
19	MASAMBA WRL	13	1,1%	12,15	158	4	2,5%	7	UB, UNIMA	Botswana, Malawi	Yes
20	ROCKSTROM J	12	1,0%	24,08	289	14	4,8%	10	WaterNet, Stockholm University	Sweden	Yes
21	GUMBO B	11	0,9%	11,64	128	6	4,7%	7	WaterNet, UZ	Zimbabwe	No
22	PARIDA BP	11	0,9%	15,91	175	5	2,9%	7	UB	Botswana	No

Rank	Authors	Articles	% of 2 699 articles	Average citations per item	Times cited	Self-citations	Self-citations as % of articles	*h*-index	Organisation	Country	WARFSA publication association
23	TWOMLOW S	11	0,9%	20,00	220	13	5,9%	10	ICRISAT	Zimbabwe	No
24	ALEMAW BF	11	0,9%	9,18	101	5	5,0%	6	UB	Botswana	No
25	GIJZEN HJ	10	0,8%	6,70	67	3	4,5%	5	Delft–UT	Netherlands	No
26	SWATUK LA	10	0,8%	12,60	126	12	9,5%	6	UB	Botswana	No
27	KASHAIGILI JJ	10	0,8%	14,80	148	8	5,4%	7	SUA	Zimbabwe	No
28	TAIGBENU AE	10	0,8%	6,10	61	4	6,6%	4	UZ, WITS	Zimbabwe	No
	TOTAL	459	17%		5 607	325					
	AVERAGE			12,89 (SADC-ExSA 8,94)	186,83		5,4% (SADC-ExSA 3,8%)	7,88			

Source: Clarivate Analytics™ Web of Science™

Key:

CUT – Chinhoyi University of Technology

Delft–UT– Delft University of Technology

UEM – Eduardo Mondlane University

ICRISAT – International Crops Research Institute for The Semi-Arid Tropics

Polytech Namibia - – Polytech Namibia (now Namibia University of Science and Technology [NUST])

SUA – Sokoine University of Agriculture

UB – University of Botswana

UCT – University of Cape Town

UDSM – University of Dar es Salaam

UKZN – University of KwaZulu-Natal

UNIMA – University of Malawi

UWC – University of the Western Cape

WITS – University of the Witwatersrand

UZ – University of Zimbabwe

Amongst the prolific water researchers from the SADC-ExSA countries, there are researchers with articles that have been cited significantly more than other researchers. With the average citation rate for all SADC-ExSA articles at 8,94, and amongst the more prolific researchers 12,89, there are researchers who have been cited in some cases at an average rate of more than 20 per article (Table 10.1). These researchers are Dr Rockstrom from Stockholm University, Prof. Wolski from the UB, Prof. Savenije from the Delft–UT in the Netherlands, and Dr Twomlow from ICRISAT in Zimbabwe. In the case of Drs Rockstrom and Twomlow, with average citation rates of 24,08 and 20,0 respectively, both have published relatively fewer articles namely 12 and 11 respectively, indicating that their articles have been cited more often than those of many other researchers.

Citation rates should further be viewed in the context of self-citation rates. From Table 10.1, it is evident that self-citation rates of authors who have published more than 10 articles are generally slightly higher but not significantly so than the self-citation rates of all water research articles from SADC-ExSA countries, which is 3,8%[38] (Table 10.1). With studies showing that self-citations can influence the *h*-index of researchers (Bartneck & Kokkelmans, 2011; Hirsch, 2005; Zhivotovsky & Krutovsky, 2008), one would have to consider these factors when interpreting the *h*-index of researchers.

In addition, from Table 10.1 it is evident, that 14 out of the 28 researchers (more than half), and predominantly the top researchers, can be associated with a research publication, emanating from the WARFSA programme. In many cases, the researchers were a co-author to the publication. This is quite significant, and will be investigated further in Chapter 11.

Finally, Table 10.1 indicates the *h*-index of the prolific researchers in the SADC-ExSA countries – the *h*-index being a computable index, which provides an indication of the “importance, significant and broad impact of a scientist’s cumulative research contribution” and could be used to provide a measure to compare different researchers (Hirsch, 2005:16572). See section 5.3.2.1 for a more detailed explanation of the *h*-index. If one were to consider that the average *h*-index for researchers who have published more than 10 articles is 7,88, it becomes evident that half of the researchers have an *h*-index greater than 7,88. In the case of Prof. van der Zaag, Dr David Love and Prof. Savenije, who have the highest *h*-index of 13 amongst these researchers, this would indicate that they have 13 articles that had been cited more than 13 times amongst their articles published in SADC-ExSA countries.

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[38] An updated analysis of SADC-ExSA water research articles based on the same query parameters for this study was done in December 2017, indicating that the average self-citation rate for water research articles in SADC-ExSA being 3,8%.

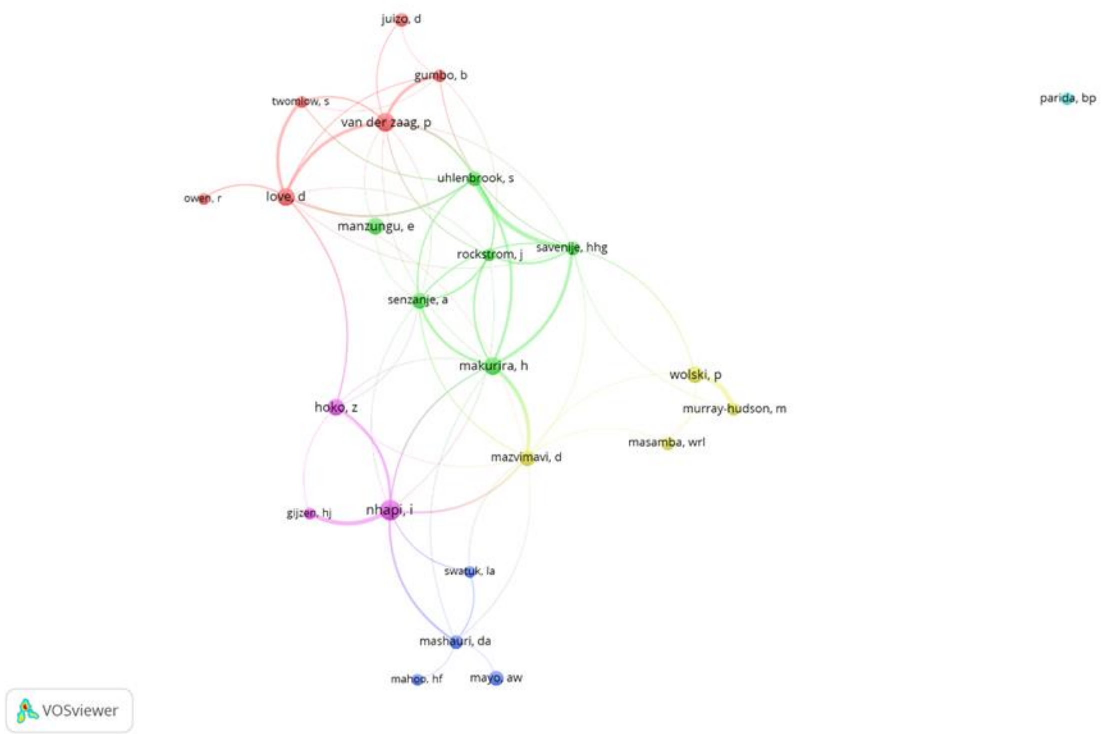


Figure 10.7: Author network visualisation of water researchers in SADC-ExSA countries who have published more than 10 articles each (1980–2016)

Source: Clarivate Analytics™ Web of Science™

In conclusion, the analysis of the authorship of research resulting from SADC-ExSA countries indicates that, as can be expected, relatively few researchers have contributed to the majority of water research in these countries, with the majority of the most prolific researchers coming from institutions in Zimbabwe, along with other SADC-ExSA countries such as Botswana, Tanzania, Namibia, Malawi and Mozambique and some researchers from the Netherlands. It is further evident, as indicated in Figure 10.7, that strong co-publication networks exist amongst these researchers, often not limited to researchers in a single institution, as in the case of South African top researchers, but with researchers from different institutions. It is known that these researchers are members of WaterNet, the largest network of water researchers in the SADC region (see WaterNet, 2016b). Given earlier findings in this study (see 9.2.1) where these researchers were largely absent when considering South African water research output, this would suggest that the WaterNet programme largely finds traction in SADC-ExSA countries. Moreover, with so many researchers present from the Delft–UT in the Netherlands amongst the more prolific (and highly cited) researchers in the SADC-ExSA countries, the support for water research from the Dutch government specifically Delft–UT is evident.

Having analysed the authorship status and trends in terms of water research from SADC-ExSA countries, it becomes evident that researchers do co-publish, as is evident from Figure 10.7. The extent of these co-publications and related trends over time is discussed in the following section.

10.2.2 Co-publication trends of SADC-ExSA water research

Since collaborative research often manifests in the co-publication of articles, the SADC region is no exception. Previous studies have indicated that, in general, the co-publication of research in the SADC region has increased, along with a decrease in single-authored articles (Boshoff, 2010; Pouris & Ho, 2013). Let us now consider the number of authors per SADC-ExSA article for the period 1980 to 2016.

10.2.2.1 Number of authors per article

An analysis of the number of authors per SADC-ExSA water research article is presented in Table 10.2, with a comparison of South African articles also presented in the table. Here it is evident that the average rate of authors per SADC-ExSA water article is 3,41, and slightly higher than the average rate per article of South African water research articles at 3,01. It is further evident that four out of five articles had multiple authors, with most articles having three authors. In South Africa, most water research articles had two authors. When it comes to articles with five and more authors, it is evident that such articles from SADC-ExSA countries are more than in the case of South African articles. There was, for example, one article with 52 authors. The findings would thus suggest that water researchers from SADC-ExSA countries publish articles with larger consortia than their counterparts in South Africa, especially articles with more than four authors.

Table 10.2: Authors per SADC-ExSA articles (1980–2016)

	Number of articles	% of articles	South Africa
Number of articles	1,217		4,666
Number of authors	4,146 *(average per article: 3,41)*		14,066 *(average per article: 3,01)*
Number of single-author articles	219	18,0%	17%
Number of multiple-author articles	997	81,9%	83%
Articles with 2 authors	246	20,2%	30%
Articles with 3 authors	275	22,6%	25%

Articles with 4 authors	200	16,4%	15%
Articles with 5 authors	132	10,8%	7%
Articles with more than 5 authors	145	11,9%	7%

Source: Clarivate Analytics™ Web of Science™

It further seems as though single-authored articles have declined since the turn of the century, to around 5% of all water research articles in recent years (Figure 10.8). Before the turn of the century, single-authored articles were regularly published. During the same period, multiple-authored articles have been increasing, notably articles with more than five authors. Since 2009, articles with more than five authors often appeared, ranging between 34% and 37% of water research articles annually. Following an initial increase in articles with two authors, these articles have remained constant, comprising 16% of all water research articles in 2016.

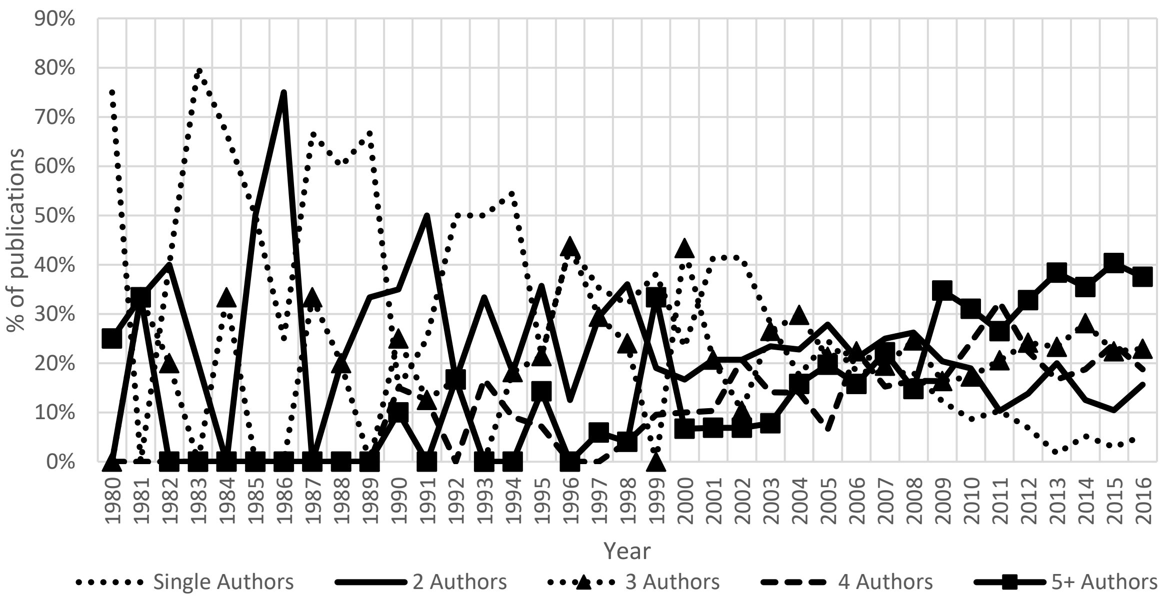


Figure 10.8: Co-authorship trends of SADC-ExSA water research articles (1980–2016)

Source: Clarivate Analytics™ Web of Science™

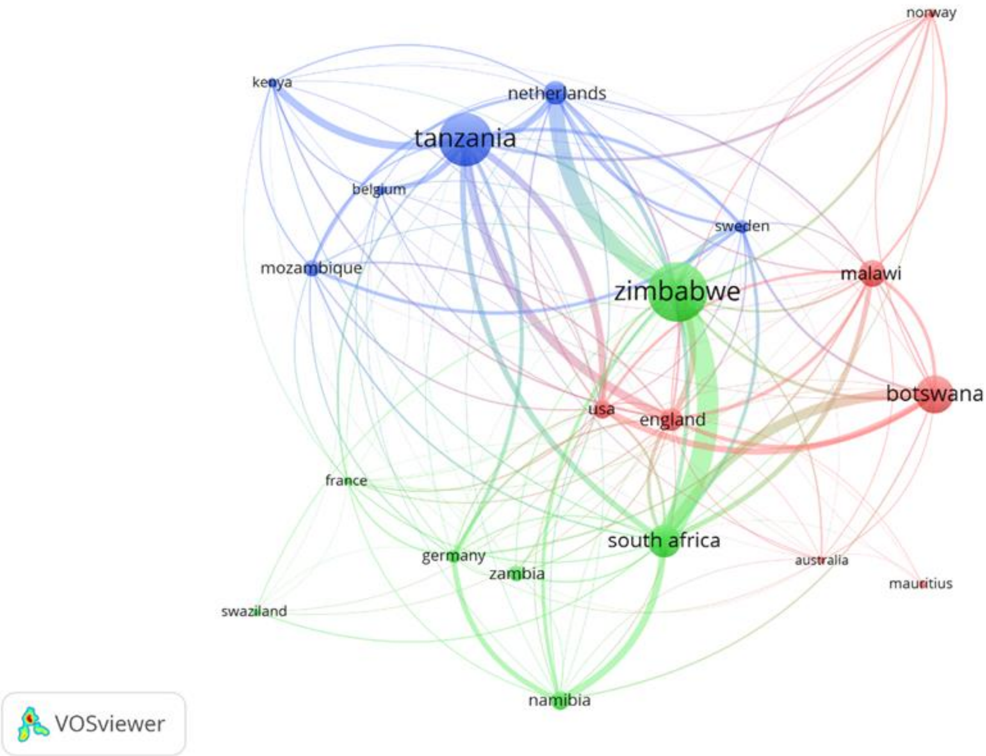
These findings are more or less in line with previous studies conducted by Boshoff (2010) and Pouris and Ho (2013). Moreover, in terms of SADC region water research, it is evident that water researchers from SADC-ExSA countries tend to co-publish more frequently with more collaborators than South African water researchers.

As established earlier in the chapter, there are researchers from countries beyond SADC-ExSA countries, who have published large numbers of articles with local researchers. The following section will discuss these countries.

10.2.2.2 Co-authorship countries

From findings earlier in this thesis (see 8.3.2.3), it is evident that researchers from SADC-ExSA countries more frequently tend to co-author articles with researchers in the SADC region and beyond, when compared to researchers from South Africa. Countries such as Tanzania, Namibia, Madagascar, Lesotho, the DRC and Angola tend to co-publish more frequently within the SADC region and beyond SADC than in their own countries, although the latter two countries should be interpreted with caution, as few water research articles have been published from these countries between 1980 and 2016. This section of the thesis starts off by making a general observation of the countries that have contributed towards water research in the SADC-ExSA countries, followed by detailed discussions on each country's co-publishing records.

Making use of VOSviewer® bibliometric data visualisation software, the most prominent SADC-ExSA countries that have published water research findings are presented in Figure 10.9. An initial analysis of publication data indicated that 94 countries have published at least one water article with SADC-ExSA countries. The analysis parameters were thus set at a minimum number of 20, which resulted in 20 countries meeting this threshold, and which assisted in identifying the most prominent network countries. Figure 10.9 thus graphically presents the dominant countries with whom SADC-ExSA water researchers co-authored articles. In addition, the thickness of the line between countries indicates the relative extent of co-authorship. The results are discussed further.



Min count of articles between countries: 20

Figure 10.9: Country network visualisation: Co-authorship of water research in the SADC-ExSA water sector (1980–2016)

Data source: Clarivate Analytics™ Web of Science™ and analysed with VOSViewer®

- **Dominant co-authorship countries:** From Figure 10.9, it is evident that various co-publishing networks exist between SADC-ExSA countries that have co-published water research. In the SADC region, the most dominant countries (not yet considering the relative strength of the link) are Zimbabwe, Tanzania, Botswana, South Africa, Malawi, Namibia, Mauritius, Mozambique, Swaziland and Zambia. From beyond SADC, European countries are include Belgium, the United Kingdom (England), France, Germany, Netherlands, Norway Sweden, the United States (North America), Australia (Australasia). Water researchers from Kenya are the only other researchers from an African country who have published more than 20 articles with researchers from SADC-ExSA countries.
- **Dominant co-authorship associations (strength of country association):** In addition, Figure 10.9 graphically presents the relative strength of co-publishing between countries, indicated by the thickness of the line between two countries. Here it becomes evident that relative strong associations exist between –
  - Zimbabwe and South Africa, the Netherlands and Sweden;

- Tanzania and countries such as the Netherlands, Kenya, Belgium, Sweden, Germany, the United Kingdom (England) and South Africa;
- Botswana and South Africa, the United States, the United Kingdom (England) and Malawi; and
- Namibia, which has having a strong association with South Africa.

These observations are however relative, with a more detailed analysis of each country's co-publishing associations discussed in more detail in the following section.

10.2.2.3 Detail of SADC-ExSA water research co-authorship collaboration

From previous chapters, it is clear that many SADC countries tend to co-author research articles with fellow researchers not from their own countries, especially in the case of Angola, the DRC, Madagascar, and to a certain extent, Namibia and Mozambique. In addition, there are countries such as South Africa, Seychelles, Tanzania and Mauritius where water researchers more often co-author articles with other researchers beyond SADC than with researchers within the region.

In the next section, the countries with whom SADC-ExSA water researchers co-publish water research are presented. The SADC countries are discussed in alphabetical order and, to provide context of water research in each country, the top 10 research areas in each country are presented. The water research output in the specific country is further elaborated. To highlight the top countries with which each SADC-ExSA country co-publishes water research further, collaborating countries are presented and ranked from 1 to 5, with 1 the country or countries with the most co-author affiliations, and 5, the 5th-ranked country or countries. The balance of the country affiliations is totalled in the category 'other'. Country affiliations are further categorised as 'all' co-author affiliations' (providing a general order of the countries where the most co-author affiliations are), 'SADC country' co-author affiliations and 'beyond SADC' co-author affiliations, to present the various country distributions of the water research co-authors. Note that in this section, a computation of the number of country affiliations per article is presented. For example, an article may have five authors, of which some authors are affiliated with one country, some in the SADC region and some beyond the SADC. The objective was to identify whether researchers in the SADC region co-author articles in the SADC region and/or beyond the SADC region.

Angola

As is evident from Table 10.3, researchers affiliated with Angolan universities and research institutions have produced 0,24% of the research in the SADC region in the period 1980–2016, with research in Angola primarily focussing on medicine or health sciences and, to a degree, engineering and earth sciences. Water research in Angola ranks low when compared with other research fields in the country, as research in die field of water resources are in the 4th quartile of research fields in the country.

Table 10.3: Top 10 research areas: Angola (1980–2016)

Rank	Research areas	% of country research	% of SADC
1	Tropical medicine	12.97	
2	Infectious diseases	11.41	
3	Public environmental occupational health	10.76	
4	Engineering	7.00	
5	Geology	6.87	
6	Parasitology	6.22	
7	Science technology and other topics	5.31	
8	Immunology	4.92	
9	Cardiovascular system cardiology	4.66	
10	Plant sciences	4.66	
	All research		0.24
108/109 (Q4)	Water resources	0.13	0.02

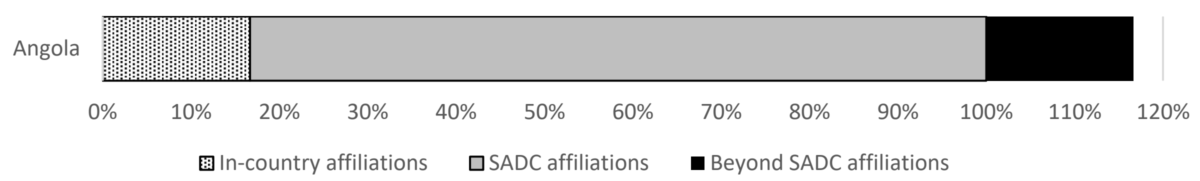
Source: Clarivate Analytics™ Web of Science™

Recently, in 2015, only one article was published in the field of water resources (comprising 0,13% of articles in Angola), with co-author partners from Botswana, Namibia, South Africa and Zambia (in the SADC) and Germany (Table 10.4). Moreover, the largest portion of co-author collaboration was with SADC countries. With only one water research article produced, which involved a researcher from Angola, this contribution comprised only 0,02% of SADC water research. However, this data should be read with caution, as it reflects only one article.

Table 10.4: Co-author country affiliations of water research in the Angola (1980–2016)

Research affiliations	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Other	Total of affiliations	Number of water research articles (% of SADC)
All research affiliations	Angola, Botswana, Germany, Namibia, South Africa, Zambia (1)					0	6	1 (0.02%)
SADC countries	Angola, Botswana, Namibia, South					0	5	

Research affiliations	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Other	Total of affiliations	Number of water research articles (% of SADC)
	Africa, Zambia (1)							
Beyond SADC	Germany (1)					0	1	



Note: Due to fractional counting, the co-authored articles were assigned to each country, resulting in the percentages not always counting up to 100%. This means that co-authors could have had more than one affiliation in any of the countries.

Source: Clarivate Analytics™ Web of Science™

Botswana

Researchers from Botswana have produced 1,66% of all articles in the SADC region between 1980 and 2016, focussing on varied research areas, namely environmental sciences, chemistry, engineering agriculture, mathematics, education and health sciences. Water research featured relatively high as a research area, ranked within the 1st quartile of research fields in Botswana, and comprising 3,8% of all research (Table 10.5). Moreover, based on the AI analysis reported on in Chapter 7 (see 7.2.2), it is evident that researchers in Botswana have increased their relative effort on water research in the country in recent years, to just over double the SADC average. This contributed towards an increase in the share of water research in Botswana.

Table 10.5: Top 10 research areas: Botswana (1980–2016)

Rank	Research areas	% of country research	% of SADC
1	Environmental sciences and ecology	9.47	
2	Infectious diseases	6.57	
3	Chemistry	6.31	
4	Engineering	6.06	
5	Geology	5.99	
6	Public environmental occupational health	5.11	
7	Agriculture	4.90	
8	Mathematics	4.30	
9	Education educational research	4.28	
10	Immunology	4.09	

Rank	Research areas	% of country research	% of SADC
	All research		1.66
12/144 (Q1)	Water resources	3.84	3.69

Source: Clarivate Analytics™ Web of Science™

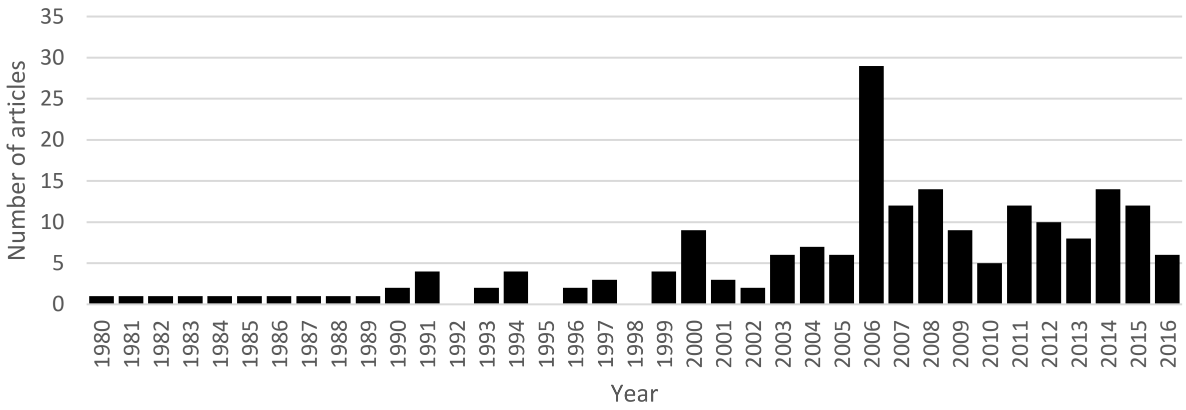


Figure 10.10: Annual distribution of water research output: Botswana (1980–2016)

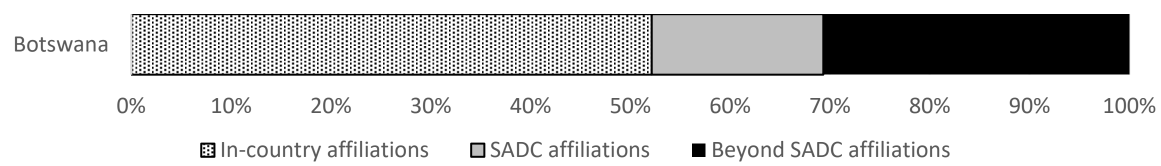
Source: Clarivate Analytics™ Web of Science™

Between 1980 and 2016, researchers in Botswana produced 194 water research articles, which comprised 3,69% of all water research in the SADC region (Table 10.5). These research outputs have been produced consistently over the years, with significant increases evident since 2000 and especially the mid-2000s. Water researchers in Botswana have regularly produced between 5 and 14 articles annually in recent years (Figure 10.10).

Where co-authorship of water research occurred beyond Botswana, collaboration was predominantly with researchers affiliated with South Africa, followed by the United States, the United Kingdom (England) and Malawi (Table 10.6). In the SADC region, countries are South Africa, followed by Malawi, Zimbabwe, Namibia and Tanzania. Countries beyond SADC are the United States, the United Kingdom (England), the Netherlands, Sweden, Switzerland and Denmark. Moreover, co-authorship collaboration was predominantly with researchers in Botswana, and then beyond SADC, followed by SADC regional co-authorship collaboration.

Table 10.6: Co-author country affiliations of water research in the Botswana (1980–2016)

Research affiliations	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Other	Total of affiliations	Number of water research articles (% of SADC)
All research affiliations	Botswana (194)	South Africa (31)	USA (21)	UK (England) (14)	Malawi (12)	100	372	194 (3,4%)
SADC countries	South Africa (31)	Malawi (12)	Zimbabwe (10)	Namibia (5)	Tanzania (3)	3	64	
Beyond SADC	USA (21)	UK (England) (14)	Netherlands (10)	Sweden (8)	Switzerland, Denmark (5)	51	114	



Note: Due to fractional counting, the co-authored articles were assigned to each country, resulting in the percentages not always counting up to 100%. This means that co-authors could have had more than one affiliation in countries.

Source: Clarivate Analytics™ Web of Science™

Democratic Republic of the Congo (DRC)

All research published by researchers affiliated with institutions from the DRC, comprised less than 1% of all research in the SADC region between 1980 and 2016 (Table 10.7). Moreover, the top research areas in the DRC primarily focussed on medical and health sciences, and environmental sciences to an extent. Previous research have suggested that a strong link exists with a country's colonial past (Boshoff, 2009; Nagtegaal & De Bruin, 1994), and that many Francophone countries have a research priority in medical sciences (Arvanitis et al., 2000), which is evident here (Table 10.7). Research into water resources is ranked in the 2nd quartile amongst all research areas in the DRC, thus suggesting that water research is fairly highly ranked in the DRC, although articles have been few (Table 10.7).

Table 10.7: Top 10 research areas: Democratic Republic of Congo (DRC) (1980–2016)

Rank	Research areas	% of country research	% of SADC
1	Public environmental occupational health	17.44	
2	Tropical medicine	17.19	
3	Infectious diseases	12.05	
4	Immunology	7.19	
5	Environmental sciences ecology	5.27	
6	General internal medicine	5.10	
7	Parasitology	4.78	

Rank	Research areas	% of country research	% of SADC
8	Plant sciences	4.62	
9	Pharmacology pharmacy	4.01	
10	Science technology other topics	3.98	
	All research		0.96
49/147 (Q2)	Water resources	0.72	0.38

Source: Clarivate Analytics™ Web of Science™

Between 1980 and 2016, researchers in the DRC have produced 22 water research articles, with the most articles resulting in the years since 2010 (Figure 10.11). These water research articles further contributed 0,38% towards water research in the SADC region (Table 10.7).

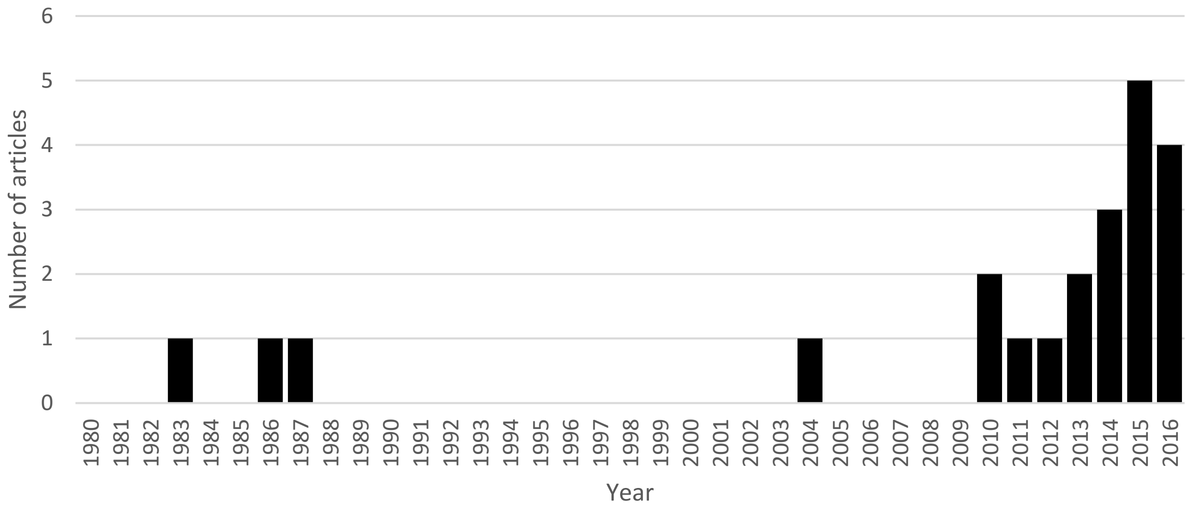


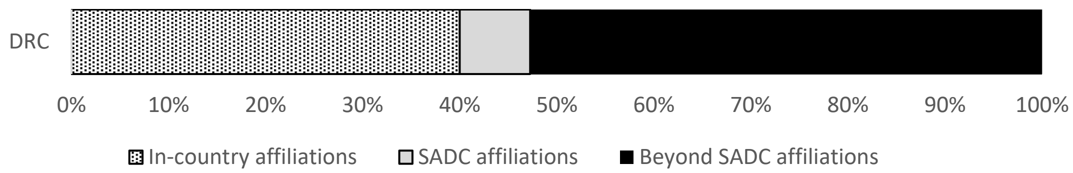
Figure 10.11: Annual distribution of water research output: Democratic Republic of Congo (1980–2016)

Source: Clarivate Analytics™ Web of Science™

The historical colonial link with Belgium is further evident when considering that Belgium is the country with whom the DRC has co-authored the most water research articles, with France and Burundi, Cameroon, Benin, DRC and Rwanda (the latter five countries in Africa) amongst the co-author collaborating countries (Table 10.8). The preference to co-publish with fellow French countries is evident. In the SADC region, researchers from the DRC have co-authored articles only with South African researchers, and beyond SADC, apart from the colonial countries already mentioned. Countries, such as the United States, Italy and Ireland, Luxembourg, Norway, the People's Republic of China, Switzerland and Vietnam to a lesser extent, are countries beyond the region with which water researchers from the DRC have co-authored articles. From the analysis, it is evident, and probably not surprising, that water researchers from the DRC tend to collaborate with other French-speaking researchers across the continent and beyond Africa.

Table 10.8: Co-author country affiliations of water research in the DRC (1980–2016)

Research affiliations	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Other	Total of affiliations	Number of water research articles (% of SADC)
All research affiliations	DRC (and Zaire) (22)	Belgium (10)	South Africa (4)	USA (3)	Burundi, France, Italy (2)	10	55	22 (0,4%)
SADC countries	South Africa (4)					0	4	
Beyond SADC	Belgium (10)	USA (3)	Burundi, France, Italy (2)	Benin, Cameroon, Ireland, Luxembourg, Norway, PR China, Rwanda, Switzerland, Vietnam (1)		0	29	



Note: Due to fractional counting, the co-authored articles were assigned to each country, resulting in the percentages not always counting up to 100%. This means that co-authors could have had more than one affiliation in countries.

Source: Clarivate Analytics™ Web of Science™

Lesotho

Between 1980 and 2016, Lesotho contributed 0,2% of all research in the SADC region, with the top research areas focussing on environmental health sciences, agriculture and related fields, such as chemistry, physics and engineering (Table 10.9). In addition, there is a focus on educational research in the country. Research into water resources ranks relatively high in Lesotho when compared with other research areas, being ranked in the 1st quartile of research areas.

Table 10.9: Top 10 research areas: Lesotho (1980–2016)

Rank	Research areas	% of country research	% of SADC
1	Public environmental occupational health	11.31	
2	Infectious diseases	6.72	
3	Area studies	6.57	
4	Agriculture	5.96	
5	Science technology other topics	5.65	
6	Chemistry	5.50	

Rank	Research areas	% of country research	% of SADC
7	Physics	5.19	
8	Education educational research	4.43	
9	Engineering	4.43	
10	Energy fuels	4.28	
	All research		0.20
18/105 (Q1)	Water resources	2.93	0.33

Source: Clarivate Analytics™ Web of Science™

Researchers in Lesotho produced 19 articles between 1980 and 2016, which was a contribution of 0,3% of water research in the SADC region (Table 10.9). This is probably not surprising, given that there are not many universities and research institutions in Lesotho.

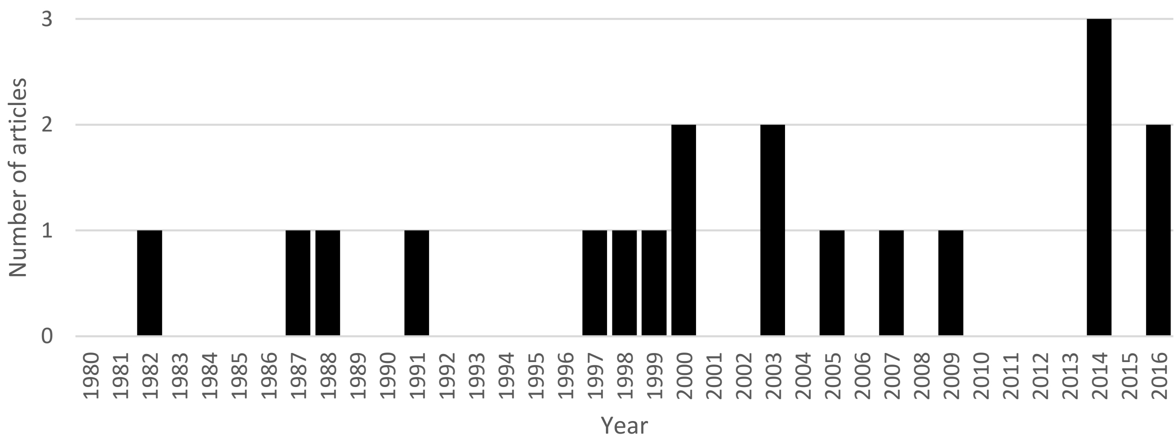


Figure 10.12: Annual distribution of water research output: Lesotho (1980–2016)

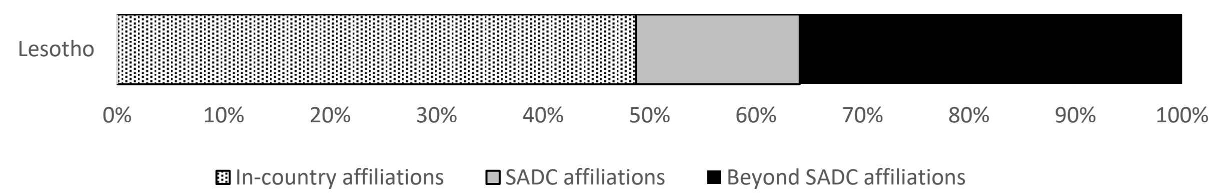
Source: Clarivate Analytics™ Web of Science™

Water researchers from Lesotho have consistently published research between 1982 and 2016, albeit at a rate of mostly one to two articles per year (Figure 10.12). In recent years, there have been slight increases, compared to other years.

Moreover, it is evident that, to a limited extent, co-authorship collaboration takes place with researchers in the SADC region in South Africa and Zimbabwe (Table 10.10). Beyond SADC, co-authorship collaboration are found with researchers in the People’s Republic of China, France, the Netherlands, Canada, the United Kingdom (England), Nigeria, Sweden, the United States and Nigeria (the latter the only other African country).

Table 10.10: Co-author country affiliations of water research in the Lesotho (1980–2016)

Research affiliations	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Other	Total of affiliations	Number of water research articles (% of SADC)
All research affiliations	Lesotho (19)	South Africa (4)	PRC (3)	France, Mongolia PR, Netherlands, Zimbabwe (2)	Canada, UK (England), Nigeria, Sweden, USA (1)	0	39	19 (0,3%)
SADC countries	South Africa (4)	Zimbabwe (2)				0	6	
Beyond SADC	PRC (3)	France, Mongolia PR, Netherlands (2)	Canada, UK (England), Sweden, Nigeria, USA (1)			0	14	



Note: Due to fractional counting, the co-authored articles were assigned to each country, resulting in the percentages not always counting up to 100%. This means that co-authors could have had more than one affiliation in countries.

Source: Clarivate Analytics™ Web of Science™

Madagascar

Researchers affiliated with institutions from Madagascar contributed less than 1% of all research in the SADC region between 1980 and 2016, with the top research areas in the natural sciences and related medical and health sciences, and most research focussing zoology, ecological environmental sciences, infectious diseases and plant sciences (Table 10.11). Water research is ranked in the 2nd quartile amongst 123 research areas in Madagascar, suggesting that it is regarded relatively high as a research field.

Table 10.11: Top 10 research areas: Madagascar (1980–2016)

Rank	Research areas	% of country research	% of SADC
1	Zoology	13.42	
2	Environmental sciences ecology	11.83	
3	Infectious diseases	8.70	
4	Plant sciences	8.02	
5	Tropical medicine	7.45	
6	Evolutionary biology	6.30	
7	Parasitology	5.97	

Rank	Research areas	% of country research	% of SADC
8	Science technology other topics	5.93	
9	Public environmental occupational health	5.49	
10	Agriculture	5.22	
	All research		0,92
51/123 (Q2)	Water resources	0.44	0.23

Source: Clarivate Analytics™ Web of Science™

Between 1980 and 2016, universities and research institutions in Madagascar have only produced 13 water research articles, which accounts for 0,2% of all water research in the SADC region (Table 10.11). Moreover, these articles were published after 2002 only, with the most published since 2012 (Figure 10.13)

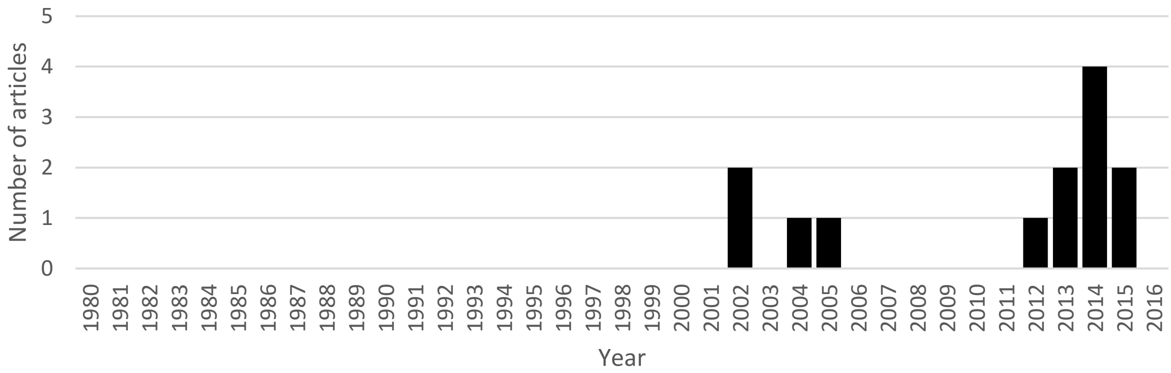


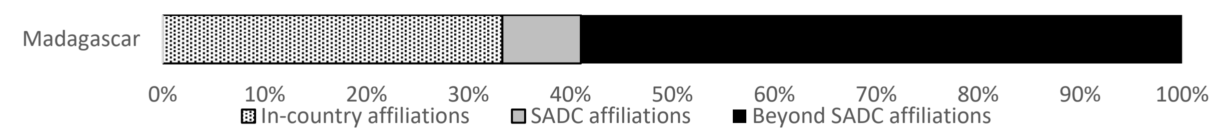
Figure 10.13: Annual distribution of water research output: Madagascar (1980–2016)

Source: Clarivate Analytics™ Web of Science™

From Table 10.12, it is further evident that where co-authorship collaboration had taken place, it was mostly with researchers beyond SADC, in Europe, with countries such as France, Germany, the United Kingdom (England), and other countries such as the United States and the People’s Republic of China. Moreover, of the water research conducted, few articles have been produced with co-authors from the SADC region, namely Mozambique, South Africa and Tanzania.

Table 10.12: Co-author country affiliations of water research in the Madagascar (1980–2016)

Research affiliations	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Other	Total of affiliations	Number of water research articles (% of SADC)
All research affiliations	Madagascar (13)	France, Germany (3)	UK (England), PRC, USA (2)	Tanzania, South Africa, Russia, Pakistan, Mozambique, Mali, Luxembourg, Kenya, Hungary, Greece, Denmark, Belgium, Austria, Australia (1)		0	39	13 (0,2%)
SADC countries	Mozambique, South Africa, Tanzania (1)					0	3	
Beyond SADC	France, Germany (3)	UK (England), PRC, USA (2)	Russia, Pakistan, Mali, Luxembourg, Kenya, Hungary, Greece, Denmark, Belgium, Austria, Australia (1)			0	17	



Note: Due to fractional counting, the co-authored articles were assigned to each country, resulting in the percentages not always counting up to 100%. This means that co-authors could have had more than one affiliation in countries.

Source: Clarivate Analytics™ Web of Science™

Malawi

Researchers from Malawi have produced the fourth most articles in the SADC region, contributing 2,09% of all research to the region between 1980 and 2016 (Table 10.13). Moreover, the top research areas in Malawi were primarily research fields related to medical and health sciences, and further comprise research areas such as public environmental health, infectious diseases, tropical medicine and immunology. Other research areas are agriculture and ecological environmental sciences. Water research in Malawi is one of the top-ranked research areas, ranked in the 1st quarter amongst 141 research areas, and comprising 1,78% of all research in the country. Researchers in Malawi has further increased the relative effort of water research in the country, based on the AI analysis reported on in Chapter 7 (refer to section 7.2.2.). In addition, since 2000, the relative effort has further increased to just more than double the SADC average (section 7.2.2.). Such increases in relative effort contribute towards water research being ranked so high in Malawi, and further to Malawi's contribution towards research output in the SADC region.

Table 10.13: Top 10 research areas: Malawi (1980–2016)

Rank	Research areas	% of country research	% of SADC
1	Public environmental occupational health	20.24	
2	Infectious diseases	15.90	
3	Tropical medicine	13.12	
4	Immunology	9.75	
5	Agriculture	7.29	
6	General internal medicine	7.17	
7	Science technology other topics	4.83	
8	Paediatrics	4.72	
9	Microbiology	4.68	
10	Environmental sciences ecology	3.52	
	All research		2.09
19/141 (Q1)	Water resources	1.78	2.06

Source: Clarivate Analytics™ Web of Science™

Researchers in Malawi have produced 118 water research articles between 1980 and 2016, contributing 2,06% of all water research in the SADC region (Table 10.13 and Figure 10.14). Here it is evident that even though single articles were produced in the 1980s and 1990s, major increases in water research occurred since 2000s, with water researchers in Malawi regularly publishing more than 10 articles per year in recent years (Figure 10.14). The results of the relative effort which Malawian researchers place on water research become even more evident in the increases in articles in recent years.

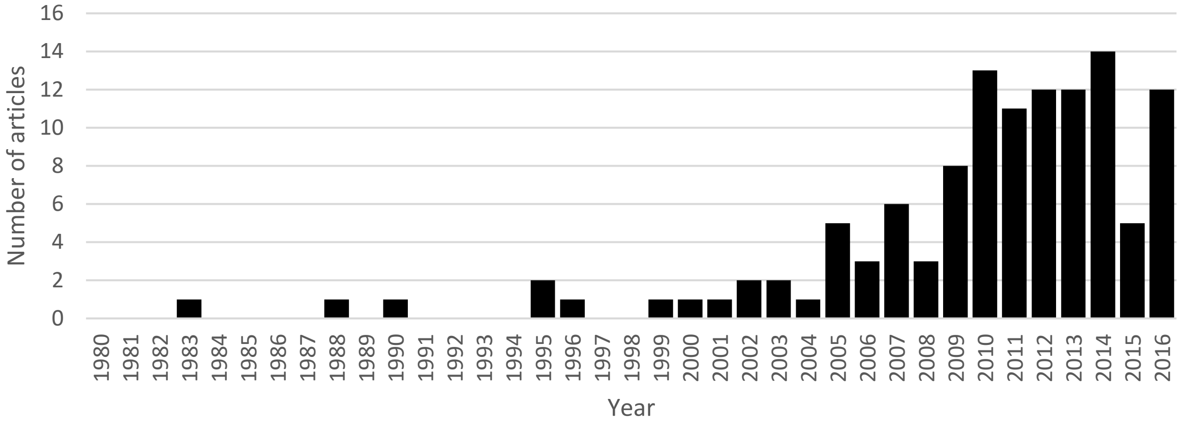


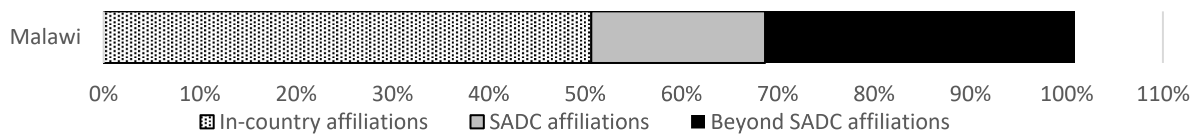
Figure 10.14: Annual distribution of water research output: Malawi (1980–2016)

Source: Clarivate Analytics™ Web of Science™

Water researchers in Malawi predominantly co-author with researchers from Malawian universities and research institutions (Table 10.14). Even though Malawian researchers co-author many articles with researchers beyond SADC, South Africa is the top collaborating country, with Botswana, Zimbabwe, Namibia, Mozambique and Tanzania other top countries in the SADC region. Co-authors from beyond SADC are from countries such as the United Kingdom (England), the United States, Germany, Norway and Scotland.

Table 10.14: Co-author country affiliations of water research in the Malawi (1980–2016)

Research affiliations	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Other	Total of affiliations	Number of water research articles (% of SADC)
All research affiliations	Malawi (118)	South Africa (16)	UK (England) (13)	Botswana (12)	USA (10)	64	233	118 (2,1%)
SADC countries	South Africa (16)	Botswana (12)	Zimbabwe (8)	Namibia (2)	Mozambique, Tanzania (2)	0	42	
Beyond SADC	UK (England) (13)	USA (10)	Germany, Norway, Scotland (7)	Netherlands (5)	Sweden (4)	22	75	



Note: Due to fractional counting, the co-authored articles were assigned to each country, resulting in the percentages not always counting up to 100%. This means that co-authors could have had more than one affiliation in countries.

Source: Clarivate Analytics™ Web of Science™

Mauritius

In the past, research in Mauritius primarily focussed on research areas related to engineering, computer science and environmental sciences (Table 10.15). Related fields are agriculture, chemistry, plant sciences and mathematics. To an extent, research further focussed on business and economics. Water research falls within the 1st quartile out of 129 research areas in Mauritius, comprising just under 1% (or 30 articles) of research in Mauritius.

Table 10.15: Top 10 research areas: Mauritius (1980–2016)

Rank	Research areas	%	% of SADC
1	Engineering	14.54	
2	Computer science	11.54	
3	Environmental sciences ecology	9.31	
4	Agriculture	9.18	
5	Chemistry	8.86	
6	Plant sciences	5.22	
7	Business and economics	4.50	
8	Mathematics	4.18	
9	Food science technology	3.77	
10	Pharmacology pharmacy	3.31	
	All research		0.69
30/129 (Q1)	Water resources	1.38	0.52

Source: Clarivate Analytics™ Web of Science™

Between 1980 and 2016, researchers affiliated with institutions in Mauritius published 30 articles, which comprised 0,5% of water research in the SADC region (Figure 10.15 and Table 10.15). Notable, however, is the very high number of articles produced in 1990, when 10 articles were produced by researchers affiliated with Mauritian universities and research institutions. A close inspection of these articles revealed that eight resulted from a symposium on the irrigation of sugar cane and associated crops, which took place in Mauritius between 18 and 22 April 1988. As highlighted previously in Chapter 8 (see 8.5), the effect of a scientific conference or symposium on research output involving local researchers cannot be underestimated, as is evident in the research output from Mauritius, especially when the general research output is relatively low. Subsequently, water researchers in Mauritius have sporadically produced articles, often no more than two per year, further confirming the decline in relative effort in water research in Mauritius. It would thus be fair to say that water researchers from Mauritius have consistently published research over the years, albeit at very low numbers, and highly influenced by a topical conference, which took place in the early 1990s.

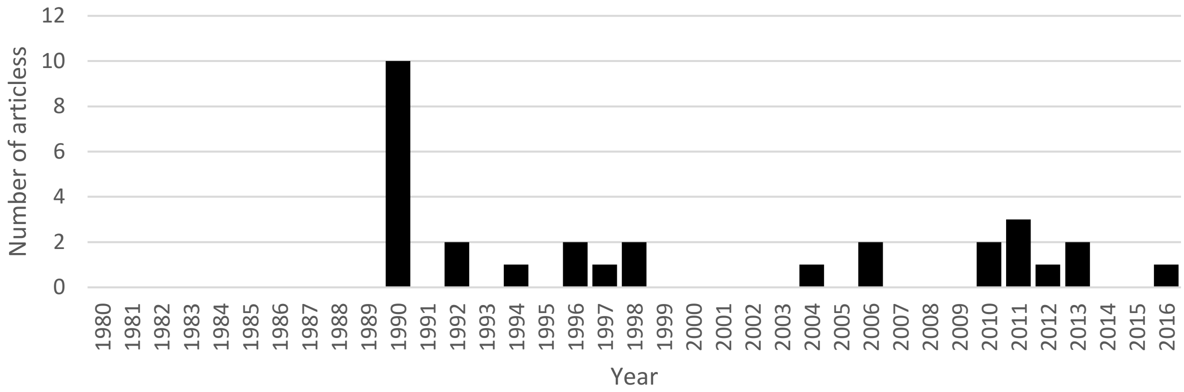


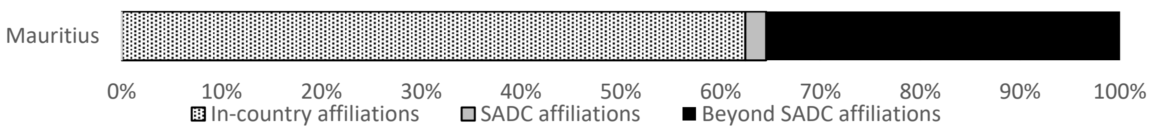
Figure 10.15: Annual distribution of water research output: Mauritius (1980–2016)

Source: Clarivate Analytics™ Web of Science™

Where articles were co-authored with other researchers, the main research affiliations were from Mauritius, followed mainly by researchers affiliated with universities and research institutions in the United Kingdom (England) – 30% of co-authored affiliations were from the United Kingdom (England) (Table 10.16). To a much lesser extent, other countries are Canada, Australia, Finland, Poland, Sweden, and the United States. In the SADC region, only one affiliation could be found with South Africa, and no other SADC country.

Table 10.16: Co-author country affiliations of water research in the Mauritius (1980–2016)

Research affiliations	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Other	Total of affiliations	Number of water research articles (% of SADC)
All research affiliations	Mauritius (30)	UK (England) (10)	Canada (2)	Australia, Finland, Poland, South Africa, Sweden, USA (1)			48	30 (0,5%)
SADC countries	South Africa (1)					0	1	
Beyond SADC	UK (England) (10)	Canada (2)	Australia, Finland, Poland, Sweden, USA (1)			0	17	



Note: Due to fractional counting, the co-authored articles were assigned to each country, resulting in the percentages not always counting up to 100%. This means that co-authors could have had more than one affiliation in countries.

Source: Clarivate Analytics™ Web of Science™

Mozambique

As in the case of many countries in the SADC region, researchers affiliated with institutions in Mozambique have contributed less than 1% towards all research in the SADC region, and primarily focussed on medicine and health sciences and related fields (Table 10.17). Fields are, public environmental health, infectious disease and tropical medicine. To an extent, research also focussed on environmental sciences and agriculture. Research into water resources accounted for 2,3% of all research in Mozambique, and are placed in the 1st quartile amongst 134 research areas in the country, thus suggesting that water research is regarded as fairly high priority.

Table 10.17: Top 10 research areas: Mozambique (1980 – 2016)

Rank	Research areas	% of country research	% of SADC
1	Public environmental occupational health	15.66	
2	Infectious diseases	13.52	
3	Tropical medicine	12.52	
4	Immunology	7.56	
5	Environmental sciences ecology	5.55	
6	General internal medicine	5.15	
7	Parasitology	5.15	
8	Agriculture	4.95	
9	Science technology other topics	4.95	
10	Cardiovascular system cardiology	4.31	
	All research		0.93
22/134 (Q1)	Water resources	2.30	1.19

Source: Clarivate Analytics™ Web of Science™

During the same period, 68 water research articles were published by researchers affiliated with Mozambican universities and research institutions, contributing 1,2% towards water research in the SADC region (Figure 10.16 and Table 10.17). As in the case of Malawi and Botswana, water research from Mozambican universities and research institutions increased significantly since 2000, with water researchers regularly publishing more than four articles per year, and even 9 and seven articles in 2014, 2015 and 2016 respectively. As in the case of Botswana and Malawi, Mozambique is one of the countries which has increased the relative effort in water research (refer to Chapter 7, section 7.2.2), above the SADC average, with this effort evident in the continued increase in articles as observed in Figure 10.16.

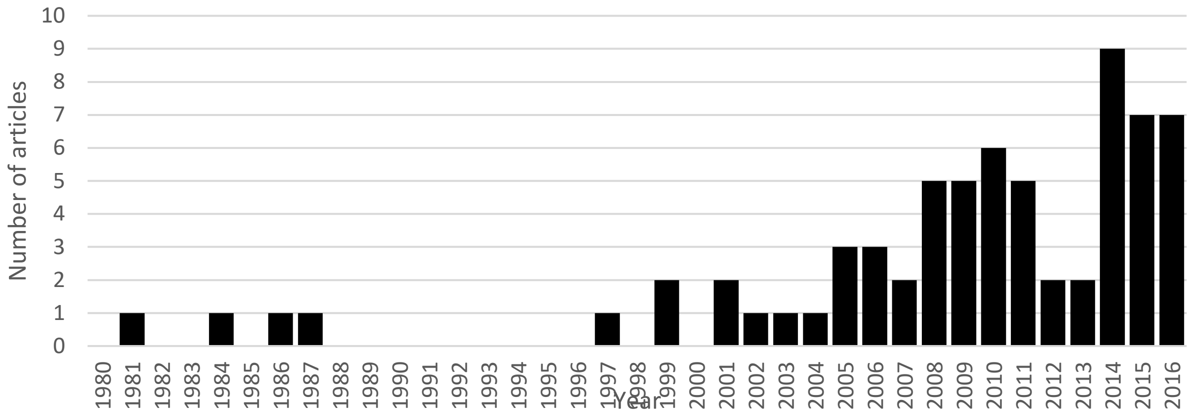


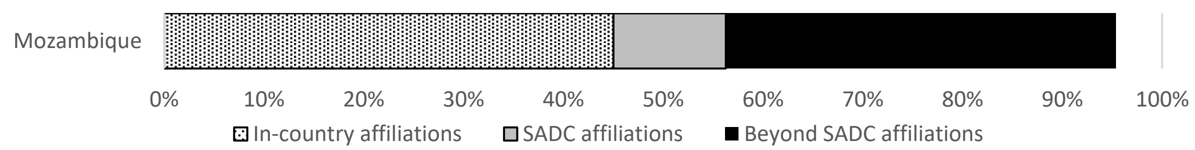
Figure 10.16: Annual distribution of water research output: Mozambique (1980–2016)

Source: Clarivate Analytics™ Web of Science™

Moreover, as evident from Table 10.18, these articles where co-authored with many researchers beyond SADC. Countries beyond SADC are Sweden, the Netherlands, the United Kingdom (England), India and to an extent, Portugal (Mozambique was a colony of Portugal from 1498 to 1975), the United States and Kenya in East Africa. In the SADC region, a few articles were published with researchers affiliated with universities and research institutions from South Africa, Tanzania, Zimbabwe and single articles with Madagascar, Malawi and Swaziland. It is thus clear that water researchers from Mozambique tend to co-publish water research rather with fellow water researchers in Europe, and then to an extent with colleagues in some SADC countries. It is interesting to note that it seems as though water researchers in Mozambique are not much bound by their Portuguese colonial past – even though Portugal is one of the top five ranked countries, it is not the top country, and there are many other English-speaking countries with which they co-publish.

Table 10.18: Co-author country affiliations of water research in the Mozambique (1980-2016)

Research affiliations	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Other	Total of affiliations	Number of water research articles (% of SADC)
All research affiliations	Mozambique (68)	Sweden (11)	Netherlands (10)	UK (England), India, South Africa (6)	Kenya, Portugal, Tanzania, USA (5)	24	151	68 (1.2%)
SADC countries	South Africa (6)	Tanzania (5)	Zimbabwe (3)	Madagascar, Malawi, Swaziland (1)		0	17	
Beyond SADC	Sweden (11)	Netherlands (10)	UK (England), India (6)	Kenya, Portugal, USA (5)	Belgium, Scotland, Switzerland (2)	5	59	



Note: Due to fractional counting, the co-authored articles were assigned to each country, resulting in the percentages not always counting up to 100%. This means that co-authors could have had more than one affiliation in countries.

Source: Clarivate Analytics™ Web of Science™

Namibia

Between 1980 and 2016, research which involved Namibian researchers have contributed 0,84% of all research in the SADC region, with by far the most research focussing on environmental sciences and related research fields, as almost 32% all research focussing on ecology, zoology and geology during this time (Table 10.19). Other research areas are science and technology studies, marine biology, astronomy, veterinary sciences, computer sciences public health and plant sciences. During the same period, water research is ranked in the 1st quartile amongst 135 research areas in Namibia, comprising just over 3% of all research, suggesting a relative high on water research in the country. In addition, since the turn of the century, water research have seen an increased focus in Namibia when compared to other research fields, referring to the AI analysis undertaken in Chapter 7 (refer to section 7.2.2).

Table 10.19: Top 10 research areas: Namibia (1980 – 2016)

Rank	Research areas	% of country research	% of SADC
1	Environmental sciences ecology	16.21	
2	Zoology	8.12	
3	Geology	7.38	
4	Science technology other topics	7.38	

Rank	Research areas	% of country research	% of SADC
5	Marine freshwater biology	5.77	
6	Astronomy astrophysics	4.92	
7	Veterinary sciences	4.39	
8	Computer science	4.32	
9	Public environmental occupational health	4.02	
10	Plant sciences	3.95	
	All research		0.84
15/135 (Q1)	Water resources	3.09	1.43

Source: Clarivate Analytics™ Web of Science™

Researchers affiliated with Namibian universities and research institutions have published 82 articles during 1980 and 2016 which is a contribution of 1,4% of all water research in the SADC region (Figure 10.17 and Table 10.19). As many SADC countries, these increases have occurred since 2000, especially since 2013, with 13 articles produced in 2014, up from around two per year in the early 2000s.

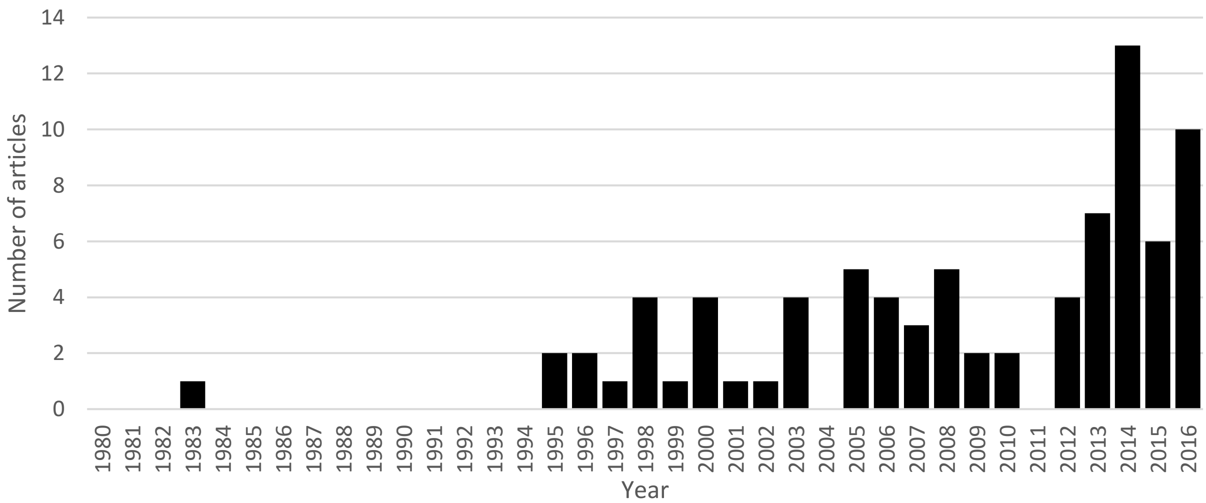


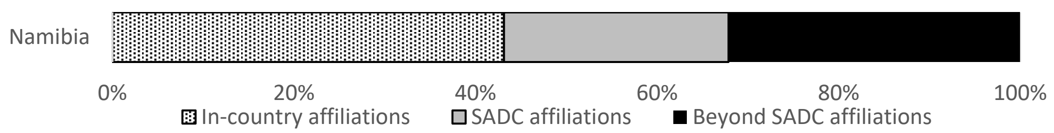
Figure 10.17: Annual distribution of water research output: Namibia (1980–2016)

Source: Clarivate Analytics™ Web of Science™

A large number of these articles were co-authored with South African and German researchers (Table 10.20). This is probably not surprising, considering that Namibia has close ties with South Africa given that the country was under the Administration of South Africa until its independence in 1990 and a German colony from 1884 to after the First World War in 1918. Coincidently, Boshoff (2009) found that the proportion of co-authored articles were the highest between Namibia and South Africa when considering all articles. Namibian water researchers further co-author articles with researchers from Zimbabwe and Botswana, and to a lesser extent with Malawi, Tanzania, Zambia and Angola in the SADC region. To a limited extent, co-publishing is evident with other countries beyond SADC, which mainly are Ghana in Africa, countries in Europe, North America and some in Asia and South America. It is thus clear that water researchers from Namibia tend to co-publish research with other researchers from countries linked to their administrative and colonial past, and to other countries in the SADC region, then beyond SADC in other countries.

Table 10.20: Co-author country affiliations of water research in the Namibia (1980-2016)

Research affiliations	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Other	Total of affiliations	Number of water research articles (% of SADC)
All research affiliations	Namibia (82)	South Africa (24)	Germany (17)	Zimbabwe (11)	Botswana (5)	51	190	82 (1,4%)
SADC countries	South Africa (24)	Zimbabwe (11)	Botswana (5)	Malawi, Tanzania, Zambia (2)	Angola (1)		47	
Beyond SADC	Germany (17)	Ghana (4)	Austria, UK (England), France, Spain, Sweden, USA (3)	Australia, Belgium, Canada, Israel, Japan, Netherlands, Scotland (2)	Colombia, Czech Rep, Denmark, Italy, PRC, Slovenia, Switzerland, Turkey (1)		61	



Note: Due to fractional counting, the co-authored articles were assigned to each country, resulting in the percentages not always counting up to 100%. This means that co-authors could have had more than one affiliation in countries.

Source: Clarivate Analytics™ Web of Science™

Seychelles

Between 1980 and 2016, most research conducted with researchers from Seychelles, focussed on environmental and related sciences, and to an extent medical and health sciences (Table 10.21). Ecological and environmental sciences, zoology and marine freshwater biology and fisheries comprising just over 50% of all research articles. Water research are ranked in the 2nd quadrant amongst 82 research areas, comprising 1,69% of all articles, thus suggesting that water research, linked to the high levels of environmental science research, has a relative high focus in Seychelles.

Table 10.21: Top 10 research areas: Seychelles (1980 – 2016)

Rank	Research areas	% of country research	% of SADC
1	Environmental sciences and ecology	20.47	
2	Public environmental occupational health	12.08	
3	Zoology	11.57	
4	Marine freshwater biology	11.07	
5	Fisheries	8.05	
6	Cardiovascular system cardiology	7.71	
7	Biodiversity conservation	6.71	
8	Science technology other topics	5.36	
9	Nutrition dietetics	5.03	
10	Neurosciences neurology	4.69	
	All research		0.19
23/82 (Q2)	Water resources	1.69	0.17

Source: Clarivate Analytics™ Web of Science™

Compared to other SADC countries, researchers affiliated with Seychelles research institutions have produced very few water research articles, producing 10 articles between 1980 and 2016, which is a contribution of 0,2% of all water search in the SADC region (Figure 10.18 and Table 10.21). This is probably not surprising, given that the island of Seychelles is one of the least populous countries in SADC, with a small population of fewer than 100 000 people and limited Universities and research institutions on the island country (World Bank, 2017). From Figure 10.18 it is further evident, that water researchers from Seychelles sporadically published articles, mostly single articles annually.

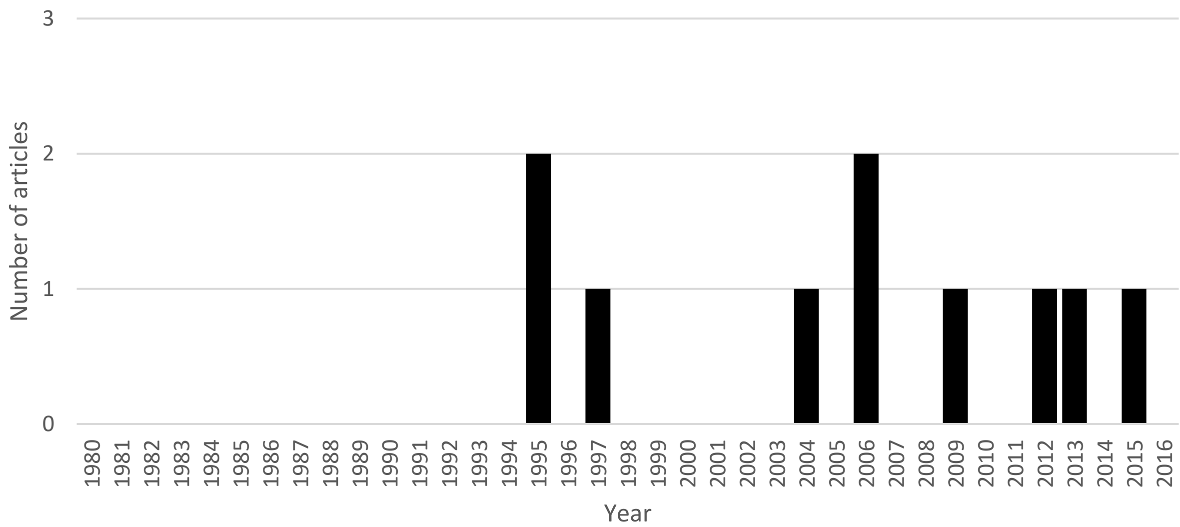


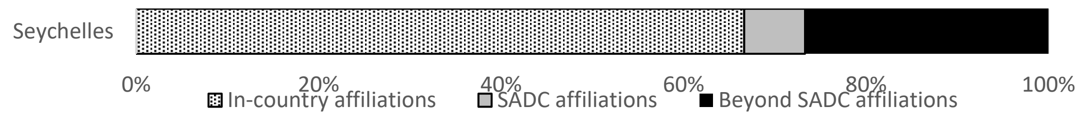
Figure 10.18: Annual distribution of water research output: Seychelles (1980–2016)

Source: Clarivate Analytics™ Web of Science™

From Table 10.22 it further evident that these articles were mostly from researchers affiliated with Universities and research institutions from the Seychelles, with single co-author affiliations with South Africa (the only SADC country) Australia, the United Kingdom (England), Sweden and the United States.

Table 10.22: Co-author country affiliations of water research in the Seychelles (1980-2016)

Research affiliations	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Other	Total of affiliations	Number of water research articles (% of SADC)
All research affiliations	Seychelles (10)	Australia, UK (England), South Africa, Sweden, USA (1)				0	15	10 (0.2%)
SADC countries	South Africa (1)					0	1	
Beyond SADC	Australia, UK (England), Sweden, USA (1)					0	4	



Note: Due to fractional counting, the co-authored articles were assigned to each country, resulting in the percentages not always counting up to 100%. This means that co-authors could have had more than one affiliation in countries.

Source: Clarivate Analytics™ Web of Science™

Swaziland

Researchers affiliated with institutions from Swaziland have contributed less than 0,27% of all research in the SADC region between 1980 and 2016, in research fields which range from mainly agriculture, zoology, infectious diseases and environmental sciences (Table 10.23). Other top research areas are public health, mathematics, engineering, related science technology topics, chemistry and immunology. Water research in Swaziland further rank relatively high in the 1st quadrant amongst 114 research areas in Swaziland, confirming the high AI and relative effort researchers from Swaziland place on water research, when compared with other research in the country (refer to Chapter 7, section 7.2.2). In addition, the relative effort researchers from Swaziland place in water research, is above the SADC average.

Table 10.23: Top 10 research areas: Swaziland (1980 – 2016)

Rank	Research areas	% of country research	% of SADC
1	Agriculture	9.19	
2	Zoology	8.61	
3	Infectious diseases	7.80	
4	Environmental sciences ecology	7.45	
5	Public environmental occupational health	7.21	
6	Mathematics	5.00	
7	Engineering	4.77	
8	Science technology other topics	4.54	
9	Chemistry	4.19	
10	Immunology	4.19	
	All research		0.27
12/114 (Q1)	Water resources	3.50	0.52

Source: Clarivate Analytics™ Web of Science™

Researchers affiliated with institutions in Swaziland have published 30 water research articles between 1980 and 2016, contributing 0,5% of all water research in the SADC region during this time (Figure 10.19 and Table 10.23). These articles were published regularly, albeit at often one or two articles per year. As in the case of many SADC countries, there has been a relative increase in annual articles since the turn of the century, with as many as five articles in 2010. Around 1990, three articles where produced from researchers affiliated with institutions in Swaziland, which can also be associated with the symposium on the irrigation of sugar cane and associated crops, which took place from 18–22 April 1988 in Mauritius.

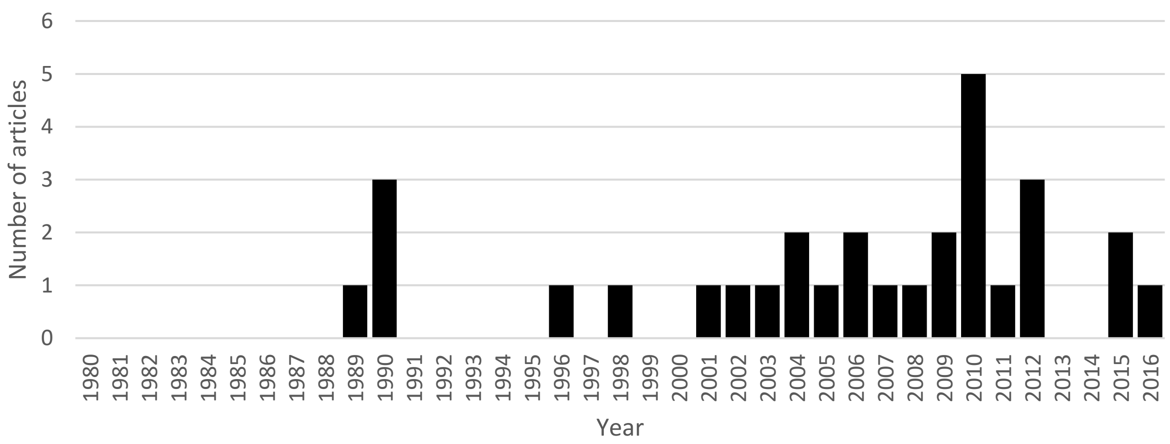


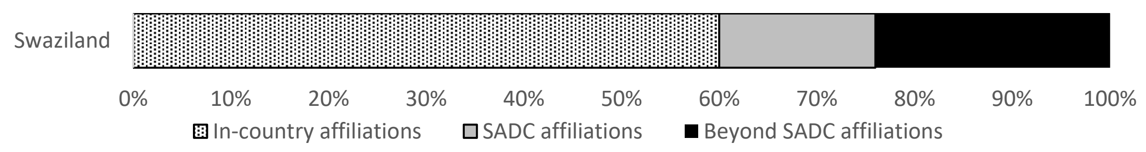
Figure 10.19: Annual distribution of water research output: Swaziland (1980–2016)

Source: Clarivate Analytics™ Web of Science™

Water researchers from Swaziland tend to co-publish with other researchers all over the world, although the number of co-articles per individual countries is limited. In the SADC region, the main countries are South Africa and Zimbabwe, and beyond SADC countries are the United Kingdom (England), the United States, and to a limited extent, Côte d'Ivoire, Denmark, France, Germany, Israel, Jamaica and Liberia.

Table 10.24: Co-author country affiliations of water research in the Swaziland (1980–2016)

Research affiliations	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Other	Total of affiliations	Number of water research articles (% of SADC)
All research affiliations	Swaziland (30)	South Africa (4)	UK (England), Zimbabwe (3)	USA (2)	Côte d'Ivoire, Denmark, France, Germany, Israel, Jamaica, Liberia, Mozambique (1)		50	30 (0.5%)
SADC countries	South Africa (4)	Zimbabwe (3)	Mozambique (1)			0	8	
Beyond SADC	UK (England) (3)	USA (2)	Côte d'Ivoire, Denmark, France, Germany, Israel, Jamaica, Liberia (1)			0	12	



Note: Due to fractional counting, the co-authored articles were assigned to each country, resulting in the percentages not always counting up to 100%. This means that co-authors could have had more than one affiliation in countries.

Source: Clarivate Analytics™ Web of Science™

Tanzania

Over the past three and a half decades, researchers affiliated with institutions from Tanzania have contributed the second most articles in the SADC region, contributing 4,74% of all articles between 1980 and 2016 (Table 10.25). The top research areas in Tanzania are mainly in the medical and health sciences, accounting for 57% of all research. Other top research areas are environmental sciences and agriculture, accounting for almost 16% of the top research undertaken during this period. Water research is ranked relatively high in the 1st quadrant amongst 148 research areas in Tanzania, accounting for almost 2% of all research undertaken in the country. Based on the AI analysis reported on in a previous chapter (see 7.2.2), it is evident that the increased focus on water research that occurred after 2000, translates into this high ranking of water research in the country. Compared to other SADC countries, Tanzanian water researchers also place a higher emphasis on water research than the SADC average (see 7.2.2).

Table 10.25: Top 10 research areas: Tanzania (1980–2016)

Rank	Research areas	% of country research	% of SADC
1	Public environmental occupational health	16.00	
2	Tropical medicine	14.10	
3	Infectious diseases	10.47	
4	Environmental sciences ecology	8.81	
5	Agriculture	7.14	
6	Parasitology	6.94	
7	General internal medicine	5.12	
8	Immunology	4.75	
9	Science technology other topics	4.49	
10	Veterinary sciences	3.53	
	All research		4.74
21/148 (Q1)	Water resources	1.97	5.17

Source: Clarivate Analytics™ Web of Science™

Researchers affiliated with Tanzanian institutions have published 296 water research articles between 1980 and 2016, which amounted to 5,2% of water research articles in the SADC region (Figure 10.20 and Table 10.25). From previous analysis in this thesis (see 7.2.1), the research output from Tanzanian instructions is the third highest after Zimbabwe (6%) and South Africa (81,4%). In addition, the higher relative effort Tanzanian researchers put into water research, when compared with the SADC average, is evident with significant increases in research output since 2003, with water researchers in Tanzania regularly publishing more than 15 articles annually (Figure 10.20). In 2007, this research output increased to 27, and in 2016, decreased again to 18.

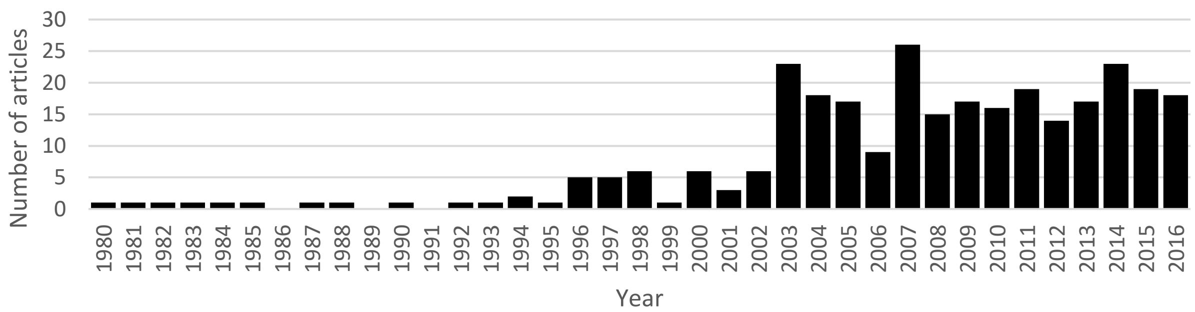


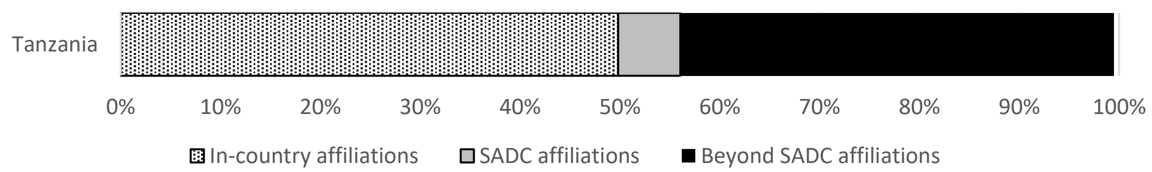
Figure 10.20: Annual distribution of water research output: Tanzania (1980–2016)

Source: Clarivate Analytics™ Web of Science™

Where these articles were co-authored with researchers outside Tanzania, a large number of the co-authors were from beyond SADC with countries such as the United Kingdom (England), Kenya (in East Africa), the Netherlands, the United States, Belgium and Germany (Table 10.26). Where articles were co-authored with researchers from SADC, it was mainly with South Africa, followed by Zimbabwe, Mozambique and, to a limited extent, Botswana and Namibia. It seems as though water researchers in Tanzania prefer to co-publish with researchers in Europe and Kenya in East Africa, more than with other researchers in the SADC region.

Table 10.26: Co-author country affiliations of water research in the Tanzania (1980–2016)

Research affiliations	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Other	Total of affiliations	Number of water research articles (% of SADC)
All research affiliations	Tanzania (296)	UK (England) (30)	Kenya (24)	Netherlands, USA (23)	South Africa (19)	178	594	296 (5.2%)
SADC countries	South Africa (19)	Zimbabwe (7)	Mozambique (5)	Botswana (3)	Namibia (2)	3	37	
Beyond SADC	UK (England) (30)	Kenya (24)	Netherlands, USA (23)	Belgium (17)	Germany (14)	127	258	



Note: Due to fractional counting, the co-authored articles were assigned to each country, resulting in the percentages not always counting up to 100%. This means that co-authors could have had more than one affiliation in countries.

Source: Clarivate Analytics™ Web of Science™

Zambia

Researchers affiliated with institutions from Zambia have contributed 1,75% of all research in the SADC region, with research in the country primarily between 1980 and 2016 focussing on medicine and health sciences (Table 10.27). During this time, research in the medicine and health sciences have contributed 70% of the top research areas in the country, with agriculture, veterinary sciences and environmental sciences contributing 5,54%, 5,07% and 4,79% respectively. Moreover, water research was ranked in the 1st quadrant amongst 140 research areas in the country, contributing just over 1% of Zambia's research during this period.

Table 10.27: Top 10 research areas: Zambia (1980–2016)

Rank	Research areas	% of country research	% of SADC
1	Public environmental occupational health	15.70	
2	Infectious diseases	14.92	
3	Tropical medicine	11.48	
4	Immunology	10.25	
5	General internal medicine	6.85	
6	Virology	6.06	
7	Agriculture	5.54	
8	Parasitology	5.09	
9	Veterinary sciences	5.07	
10	Environmental sciences ecology	4.79	
	All research		1.75
31/140 (Q1)	Water resources	1.25	1.20

Source: Clarivate Analytics™ Web of Science™

Researchers affiliated with institutions in Zambia have published 69 articles between 1980 and 2016, contributing 1,2% to the overall water research output in the SADC region (Figure 10.21 and Table 10.27). These articles have been published regularly over the years, with increases evident since the late 1990s. However, over the years, the annual rate of water research articles has gradually declined from a high of nine articles in 2001, to two, three and four articles per year in most recent years. Most recently, there has been a gradual increase again, and it will be interesting to see whether this increase can be maintained. It does seem as though Zambian researchers place a high emphasis on other research fields such medicine and health sciences, as these research areas not only make up the majority of research output from Zambia, but the relative in-country effort Zambian researchers place on water research, has also been below the SADC average (refer to Chapter 7, section 7.2.2).

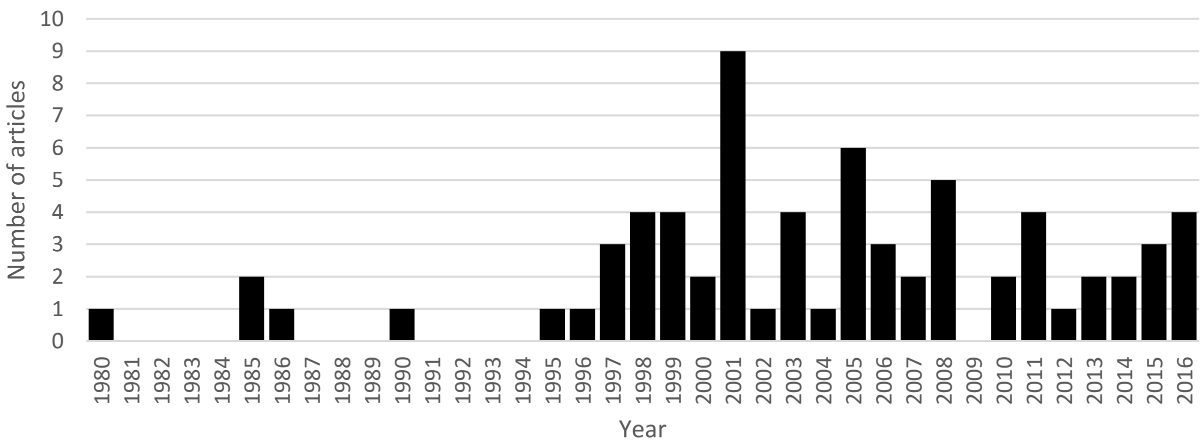


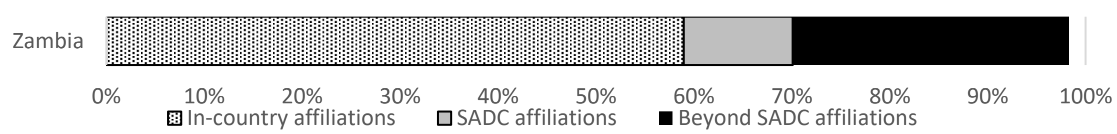
Figure 10.21: Annual distribution of water research output: Zambia (1980–2016)

Source: Clarivate Analytics™ Web of Science™

From Table 10.28 it is further evident that, although most articles were published by researchers affiliated with Zambian institutions, a fair number have been co-authored with other researchers beyond SADC in countries such as the United Kingdom (England), the Netherlands, Switzerland, Denmark, Germany and Uganda (in East Africa). Even though many articles have been co-authored with researchers beyond the SADC, researchers from South Africa, Zimbabwe, Botswana, and to a limited extent, Namibia, Angola and Tanzania have also co-authored with Zambian water researchers.

Table 10.28: Co-author country affiliations of water research in the Zambia (1980–2016)

Research affiliations	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Other	Total of affiliations	Number of water research articles (% of SADC)
All research affiliations	Zambia (69)	South Africa (5)	UK (England), Netherlands, Switzerland (4)	Denmark, Germany, Zimbabwe (3)	Botswana, Namibia, Uganda (2)	16	117	69 (1.2%)
SADC countries	South Africa (5)	Zimbabwe (3)	Botswana, Namibia (2)	Angola, Tanzania (1)		0	13	
Beyond SADC	UK (England), Netherlands, Switzerland (4)	Denmark, Germany (3)	Uganda (2)	Vietnam, Thailand, Scotland, PR China, Nicaragua, Mali, Japan, Italy, France, Bolivia, Belgium, Australia, Argentina (1)		0	33	



Note: Due to fractional counting, the co-authored articles were assigned to each country, resulting in the percentages not always counting up to 100%. This means that co-authors could have had more than one affiliation in countries.

Source: Clarivate Analytics™ Web of Science™

Zimbabwe

Researchers affiliated with institutions from Zimbabwe have contributed 3,26% of all research in the SADC region between 1980 and 2016, the third highest in the region after South Africa (83,9%) and Tanzania (4,7%) (Table 10.29). During this period, the top research areas were mainly in the fields of medicine and health sciences (35,67%) and agriculture and related fields (31,88%). Water research fell just outside the top 10 research areas (ranked 11th) and in the 1st quadrant of research areas in the country, contributing 3,3% of research in Zimbabwe, highlighting a relative high focus on water research in the country. This is confirmed when considering the AI calculation reported on in Chapter 7 (see 7.2.2), which indicates that water research in Zimbabwe has experienced a dramatic increase in relative effort compared to other research fields, increasing fourfold since the turn of the century. In addition, Zimbabwe's relative effort was more than double that of the SADC average since the turn of the century, and translates into the high research outputs observed.

Table 10.29: Top 10 research areas: Zimbabwe (1980–2016)

Rank	Research areas	% of country research	% of SADC
1	Agriculture	11.41	
2	General internal medicine	8.96	
3	Infectious diseases	8.06	
4	Public environmental occupational health	7.92	
5	Environmental sciences ecology	7.83	
6	Immunology	6.39	
7	Veterinary sciences	5.49	
8	Tropical medicine	4.34	
9	Geology	3.82	
10	Plant sciences	3.33	
	All research		3.26
11/148 (Q1)	Water resources	3.30	5.95

Source: Clarivate Analytics™ Web of Science™

The increase in water research has culminated in researchers affiliated with Zimbabwean institutions contributing 341 articles between 1980 and 2016, or 6% of all water research in the SADC region (Figure 10.22 and Table 10.29). This water research output is the second highest in the SADC region, after South Africa (81,4%). Since 1980, water researchers affiliated with Zimbabwean institutions have regularly published articles, with significant increases recorded since the late 1990s, after which Zimbabwean water researchers constantly published more than 15 articles per year between 2002 and 2008. Between 2008 and 2015, there has been a relative decline in water research output, with sporadic increases in 2011 and 2014 (Figure 10.22). In 2016, water research output has significantly increased to 38 articles, the highest output to date. The reason for this dramatic increase is unclear, as no articles from 2016 are associated with any specific conference, although many articles were published in the journals *Physics and Chemistry of the Earth* and *Water alternatives: an interdisciplinary journal on water, politics and development* (seven articles each). It would be interesting to follow this sudden increase in future to determine whether this trend continues.

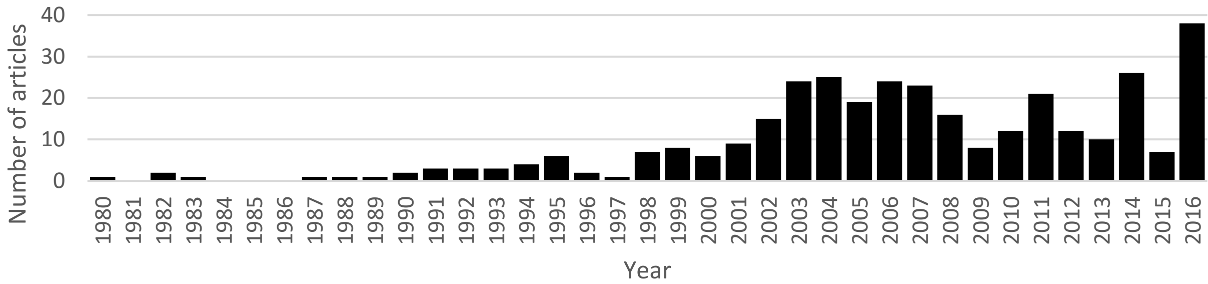


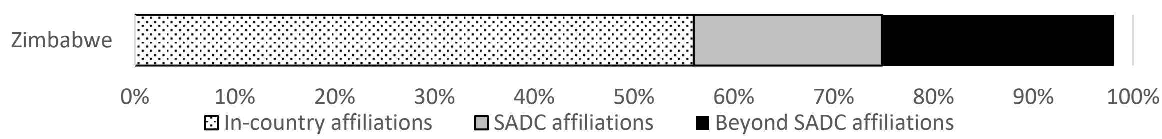
Figure 10.22: Annual distribution of water research output: Zimbabwe (1980–2016)

Source: Clarivate Analytics™ Web of Science™

In terms of the co-publishing of water research articles, a fair amount of water research has been co-authored with researchers from the SADC region and beyond the SADC, with countries namely South Africa, the Netherlands, the United Kingdom (England) and Sweden (Table 10.30). To an extent, co-authors affiliated with institutions from other SADC countries are those from Botswana, Malawi and Tanzania. Beyond SADC, other countries are Norway, the United States and Australia.

Table 10.30: Co-author country affiliations of water research in the Zimbabwe (1980–2016)

Research affiliations	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Other	Total of affiliations	Number of water research articles (% of SADC)
All research affiliations	Zimbabwe (341)	South Africa (68)	Netherlands (48)	UK (England) (22)	Sweden (16)	114	609	341 (6.0%)
SADC countries	South Africa (68)	Namibia (11)	Botswana (10)	Malawi (8)	Tanzania (7)	11	115	
Beyond SADC	Netherlands (48)	UK (England) (22)	Sweden (16)	Norway, USA (10)	Australia (6)	29	141	



Note: Due to fractional counting, the co-authored articles were assigned to each country, resulting in the percentages not always counting up to 100%. This means that co-authors could have had more than one affiliation in countries.

Source: Clarivate Analytics™ Web of Science™

In conclusion, although this section of the thesis focusses on water research co-authorship from SADC countries excluding South Africa, findings such as the links between SADC countries and their colonial past are in line with other studies (Boshoff, 2009). Examples are the DRC and its research associations with Belgium, and Namibia and South Africa, where Namibia was under an administration with South African until its independence in 1990.

Several SADC-ExSA countries have further increased their water research since the turn of the century, such as Botswana, Lesotho, Madagascar, Malawi, Mozambique, Namibia, Swaziland, Tanzania, Zambia and Zimbabwe. In addition, some SADC-ExSA countries have significantly increased their research output, such as Malawi, Tanzania and Zimbabwe, where it is further well known that UZ and UDSM are major universities in the WaterNet master's degree programme in Integrated Water Resource Management (IWRM).[39] This programme has produced no fewer than 524 graduates between 1999 and 2013, and is highly supported by the Dutch government (Kileshye-Onema, 2014). Moreover, this support is evident in that researchers affiliated with the Netherlands feature in both these countries as major co-publication countries.

It is further evident that most water researchers in SADC-ExSA countries collaborate with other scientists in the same country (national collaborations) with the exception being Angola, the DRC, Madagascar and Namibia, where researchers have co-authored articles with researchers from outside their countries. Given the large number of research outputs from the SADC region by South African researchers, it is probably not surprising that South African researchers feature as collaborators in most SADC countries. The exceptions are Mozambique and to some extent Zambia, while Zimbabwe and Botswana feature more often as SADC collaborators.

Thus far in this chapter, we have discussed research output and authorship trends from water research produced in SADC-ExSA countries. Our attention now turns to the analysis of the citations of the water research emanating from these countries.

10.3 Citation analysis of water research articles in SADC-ExSA countries

If one were to exclude water research articles published by South African institutions from the SADC water research articles, then 1 217 water research publications were produced from SADC-ExSA countries and have been cited 10 086 times[40] between 1980 and 2016, with an average citation score of 8,28 per article. Moreover, since the turn of the century, water research from SADC-ExSA countries has increased significantly (Figure 10.23). As further evident from Figure 10.23, the average number of citations for articles published in specific

[39] For more detail on the WaterNet master's degree programme, see section 6.3.1.
[40] Include self-citations.

years, varies significantly. In some years, such as 1982, five articles were published, which were cited 0,4 times on average. Four years later, four articles were published, which were cited 18,25 times on average, and in 1992, six articles were published where were cited 4,3 times on average. Given the few articles published, the large differences in the annual average citation score can be expected, as one highly cited article could significantly influence the average citation score. After 1992, there was a general increase in the average citation score, which coincided with a general increase in the number of articles. Since the turn of the century, the average citation score declined, while water research output stabilised at between 49 (in 2009) and 76 articles (in 2006). Even though the number of articles increased again since around 2009, the average citation score for the articles continues to decline, which can be attributed to the time lag it takes for article to be cited after publication. The trends observed in Figure 10.23 would suggest that the greater awareness of water research, coupled with the increase in research output, contributed towards the declining average citation score, as researchers have easy access to a broad range of research, along with increased access to articles from beyond SADC-ExSA countries.

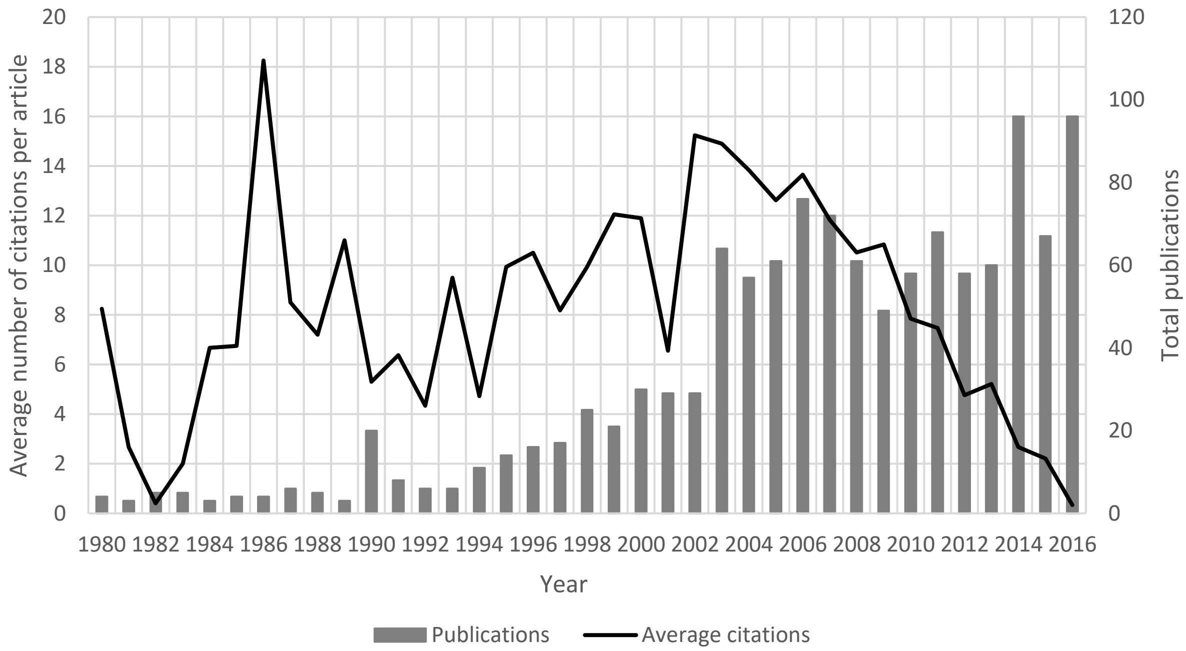


Figure 10.23: Average citation score of SADC-ExSA water research articles in relation to the total number of articles published (1980–2016)

Source: Clarivate Analytics™ Web of Science™

Having established that article output in SADC-ExSA countries has increased significantly over time, and that articles from specific years have been cited more often than those from other years, Table 10.31 present the article and citation distribution in citation ranges of 10, 100 to

500 and more than 500. Here it is evident that 21% of water research published between 1980 and 2016 by SADC-ExSA countries has never been cited. This is followed by 54% of the articles being cited between 1 and 10 times since their publication at an average citation rate of 4,19 citations per article. From Table 10.31 it is further evident that there are four articles that have collectively received 5,5% of all citations.

Table 10.31: Distribution of SADC-ExSA water research articles and citations (1980–2016)

Citation range	Number of articles	% of articles	Number of citations	% of citations	Average number of citations
0	260	21,36%	0	0,00%	
1–10	661	54,31%	2 768	27,44%	4,19
10–20	169	13,89%	2 457	24,36%	14,54
20–30	56	4,60%	1 366	13,54%	24,39
31–40	35	2,88%	1 229	12,19%	35,11
41–50	16	1,31%	732	7,26%	45,75
51–60	10	0,82%	545	5,40%	54,50
61–70	4	0,33%	265	2,63%	66,25
71–80	1	0,08%	79	0,78%	79,00
81–90	1	0,08%	86	0,85%	86,00
91–100	0	0,00%	0	0,00%	
100–500	4	0,33%	559	5,54%	139,75
500+	0	0,00%	0	0,00%	
Totals	**1 217**	**100%**	**10 086**	**100%**	
Average citation rate			**8,29**		

Source: Clarivate Analytics™ Web of Science™

By further analysing the annual distribution of these articles, as presented in Figure 10.24, it becomes evident that, as can be expected, the majority of articles which had no and fewer than 10 citations in total, have been published in recent years.

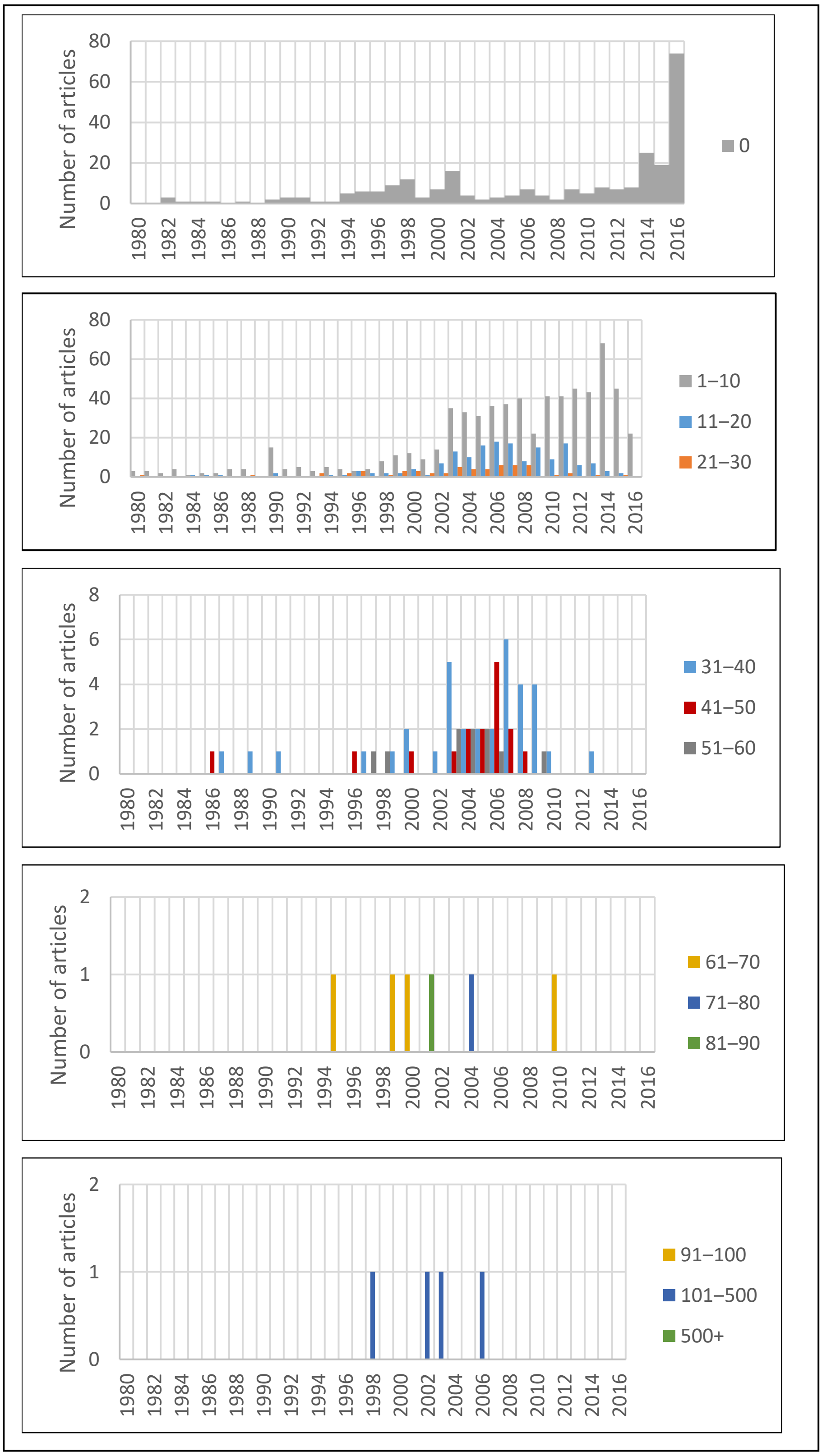


Figure 10.24: Annual distribution of SADC-ExSA water research articles and citations (1980–2016)

Source: Clarivate Analytics™ Web of Science™

From Figure 10.24, it is further evident there were quite a few articles published between 2003 and 2009, which had been cited more than others, which coincides with the initial period when many SADC-ExSA countries experienced significant increases in water research articles. This period further coincides with the launch of the annual WaterNet/WARFSA/GWP SA symposium in the early 2000s, which saw significant funding through the WARFSA programme, which was spent on water research in SADC-ExSA countries. The full extent of this will be discussed in the next chapter, when an analysis of knowledge produced from the WARFSA programme will be presented.

Moreover, from Figure 10.24, it is further evident that there were no articles published since 2011, which had received more than 60 citations, with the most recent article published in 2010. The four articles, which had been cited more than 100 times, where published in 1998, 2002, 2003 and 2006. This can be expected, as it often takes time for articles to be cited. On the other hand, there might be articles, which were published more recently, with not as many total citations, but which still have been cited more than the average article. For this reason, the average number of citations per year was calculated, with the results presented in Table 10.32 and Figure 10.25, indicating the number of articles and the annual distribution of the articles with an annual average citation rate of more than five citations per year. Here it is evident that there are 15 articles, which have been cited between 5 and 10 times on average per year, and three articles, which have been cited, on average, between 11 and 15 times per year, and no articles with an average annual citation rate of more than 16 per year.

Table 10.32: Water research articles in SADC-ExSA countries with an average of more than five citations per year (1980–2016)

	Annual average citation between			
	5 and 10 per year	11 and 15 per year	16 and 20 per year	20+ per year
Number of articles	15	3	0	0

Source: Calculated from data obtained from Clarivate Analytics™ Web of Science™

The distribution of articles with an average annual citation rate of more than five citations per year is presented in Figure 10.25. First, there are three articles with an average annual citation rate of between 11 and 15 per year, with two of the four articles published quite a few years ago, in 2002 and 2003 respectively. This would suggest that these articles have been of value to the science community over a long period. The first two articles are those by Nyanhongo, Gomes, Gubitz, Zvauya, Read, & Steiner, W. (2002) and King, Brown and Sabet (2003). These articles have been cited, on average, 11,86 and 11,42 times respectively per year since their publication. The more recent articles, which have caught the attention of the science community, are by Sorensen, Lapworth, Nkhuwa, Stuart, Gooddy, Bell et al. (2015 and Repo, Warchoł, Bhatnagar, Mudhoo, & Sillanpää (2013), and were published in *Water Research*, with an annual average citation rate of 12,5 and 10 respectively. It would be interesting to follow these articles to see whether they can maintain the relatively high citation rates.

Other articles that have received on average between 5 and 10 citations per year, are presented in Figure 10.25. Here it is evident that the 15 articles have been published over a longer period, between 1998 and as recent as 2016. One of these articles, by Lorup, Refsgaard and Mazvimavi (1998), was published in the *Journal of Hydrology*. More recently, there have been a few articles that have, in a relatively short time, caught the attention of researchers. The most recent three articles, which have been cited relatively more by the science community, are by Döll, Jiménez-Cisneros, Oki, Arnell, Benito, et al. (2015), published in the journal *Hydrological Sciences Journal* (*Journal Des Sciences Hydrologiques*), Zhang, J., Zhang, Q., Sun, Gao, Germain, & Abro, (2015), published in *Environmental Earth Sciences*, and most recently, one by Gaj, Beyer, Koeniger, Wanke, Hamutoko & Himmelsbach (2016) published in *Hydrology and Earth System Sciences*.

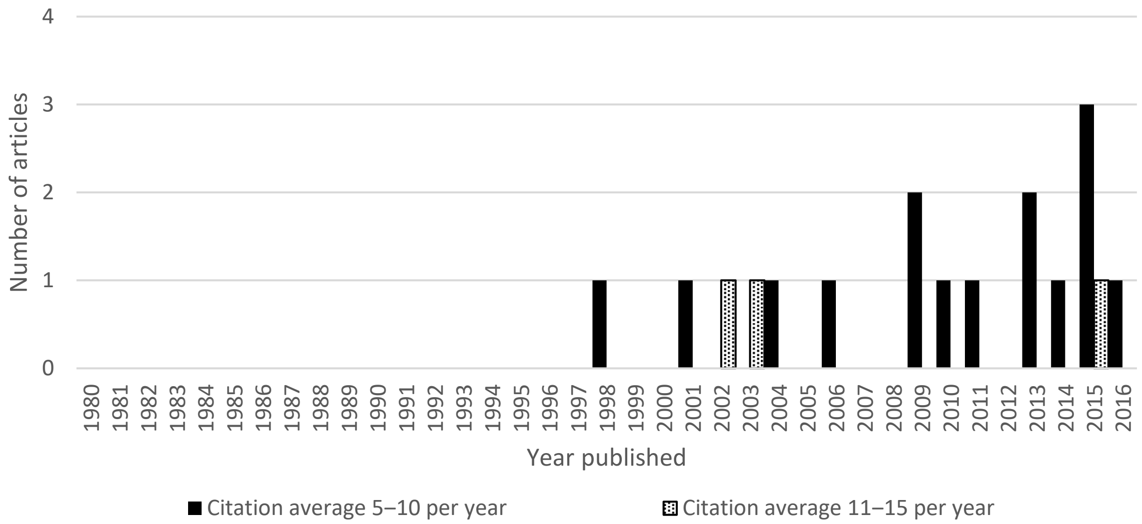


Figure 10.25: Distribution per year of water research articles with high average number of citations from the SADC-ExSA countries

Source: Clarivate Analytics™ Web of Science™

In conclusion, it is clear that only a few articles catch the attention of the science community and stay relevant over the years. Some continue to be relevant over a very long period of time, and other less so. The following sections will further investigate the citation trends of water research from SADC-ExSA countries, to understand better how articles were cited over the years.

10.3.1 Citation impact

In previous chapters 8 and 9, the citation scores and citation rates of water research in SADC and from South Africa were presented, where it further became evident that the citation data need to be normalised, to consider factors. These factors include the degree to which references from other fields are cited, differences amongst fields in the average number of cited references per publication, the way the number of citation always increase over time and the average age of cited references, and for these reasons, the mean normalised citation score (MNCS) is calculated (Leydesdorff et al., 2011; Waltman et al., 2011). For a more detailed discussion on the MNCS, refer to section 5.3.2.1).

In addition, citation scores are normalised by the number of years since articles were published. Considering citation data from water research from SADC countries where South African publications are excluded, the average annual citation scores are presented in Table 10.33 for the period between 1980 and 1999 and in Table 10.34 for the period between 2000 and 2016, with the annual distribution of citation data presented in Figure 9.13., In addition, the MNCS-values of water research in SADC-ExSA countries are also listed in Mean normalised citation scores (MNCS) of SADC-ExSA water research publications (1980–2016) and Figure 8.16.

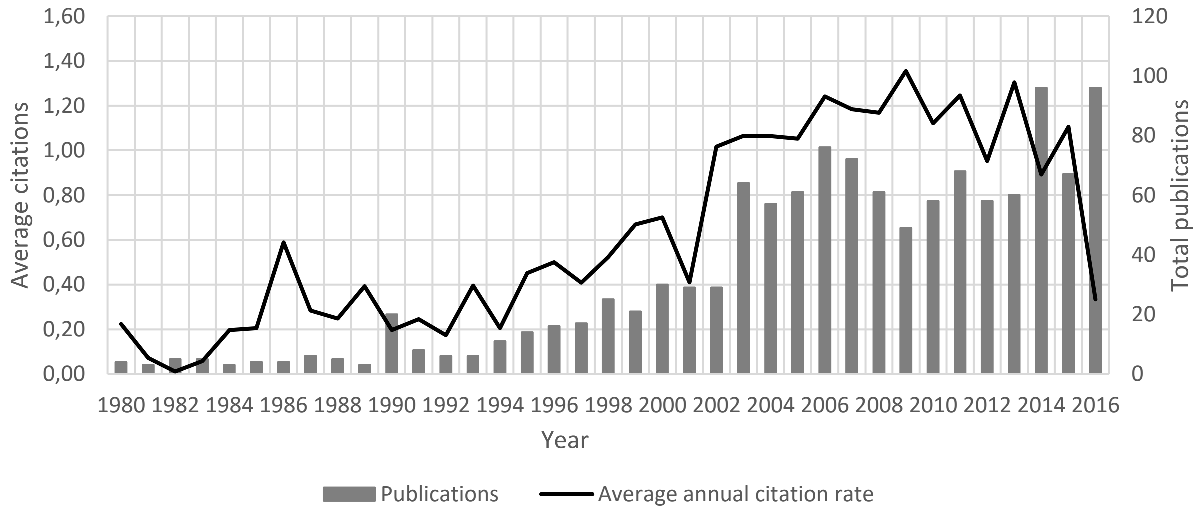


Figure 10.26: Average annual citation rate of SADC-ExSA water research (1980–2016)

Source: Clarivate Analytics™ Web of Science™

First, the annual citation scores are considered (Figure 9.13), where it is evident few water research articles were published before the century, at less than 30 articles annually. This was also discussed in more detail in chapter 7 (section 7.2.1). During this time, articles were increasingly cited, with the increase in publications. Significant though is the dramatic increase in water research publications in 2003 and 2006, to between 57 and 76 articles per year. The significant increase in citations of articles published at the turn of the century is also evident in the significant increase average annual citation rate, which continue for articles published in 2009. More recent articles are cited less, which can be attributed to the time lag it takes for publications to be cited since the publication of articles. What is of interest is the sudden increase in water research publications from these SADC-ExSA countries in the early 2000s, which coincide with the implementation of the first two phases of the WARFSA – this will be investigated in more detail in the following chapter 11.

Table 10.33: Citations of SADC-ExSA water research articles (1980–2000)

Year	Total articles (A)	Citations per year																					Total number of citations (1980–2016) (B)	Average number of citations (1980–2016) C=(B/A)	Average annual citation rate (D=C/number of years)
		80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00			
1980	4	1	1	3	2	4	1	0	1	0	1	1	1	0	1	1	0	1	0	0	1	1	33	8,25	0,22
1981	3	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	8	2,67	0,07
1982	5		0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0,40	0,01
1983	5			0	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	10	2,00	0,06
1984	3				0	1	0	0	1	1	0	1	1	0	0	1	0	0	1	0	0	1	20	6,67	0,20
1985	4					0	0	1	2	1	1	0	2	1	1	1	0	0	1	1	0	0	27	6,75	0,20
1986	4							0	2	2	1	7	3	3	2	3	3	4	0	1	3	5	73	18,25	0,59
1987	6								1	3	1	0	2	0	0	2	0	1	3	2	0	2	51	8,50	0,28
1988	5									0	0	1	1	0	2	2	1	2	5	1	1	0	36	7,20	0,25
1989	3										1	1	1	2	2	1	0	1	1	1	1	1	33	11,00	0,39
1990	20											0	7	2	1	0	2	3	3	4	6	1	106	5,30	0,20
1991	8												0	0	1	0	2	0	2	2	3	3	51	6,38	0,25
1992	6													0	1	1	3	2	1	2	2	2	26	4,33	0,17
1993	6														0	0	3	2	5	1	2	1	57	9,50	0,40
1994	11															0	0	2	5	1	7	2	52	4,73	0,21
1995	14																0	7	8	12	9	8	139	9,93	0,45
1996	16																	0	8	5	6	3	168	10,50	0,50
1997	17																		0	3	1	5	139	8,18	0,41
1998	25																			0	3	5	248	9,92	0,52
1999	21																				9	4	253	12,05	0,67
2000	30																					2	357	11,90	0,70
TOTAL	**216**	**1**	**1**	**3**	**3**	**7**	**1**	**1**	**10**	**7**	**5**	**11**	**18**	**8**	**11**	**12**	**15**	**25**	**43**	**36**	**55**	**47**	**1889**	**8,75**	

Note: This table should be read in conjunction with Table 10.34

Source: Clarivate Analytics™ Web of Science™

Table 10.34: Citations of SADC-ExSA water research articles (2001–2016)

		Citations per year																		
Year	**Total articles**	**01**	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**Total number of citations (1980–2016) (B)**	**Average number of citations (1980–2016) C=(B/A)**	**Average annual citation rate (D=C/number of years)**
2001	29	0	5	6	10	5	5	16	13	14	12	22	15	13	12	17	25	190	6,55	0,41
2002	29		0	18	25	31	35	35	41	33	30	36	30	35	29	29	35	442	15,24	1,02
2003	64			7	23	51	62	76	72	80	69	82	74	102	68	109	79	954	14,91	1,06
2004	57				2	42	56	66	67	81	58	75	57	81	72	63	68	788	13,82	1,06
2005	61					1	47	44	63	75	78	74	60	81	79	70	98	770	12,62	1,05
2006	76						6	37	97	91	91	113	105	135	127	88	147	1037	13,64	1,24
2007	72							7	52	64	88	111	87	119	103	105	116	852	11,83	1,18
2008	61								5	45	57	96	78	97	77	86	100	641	10,51	1,17
2009	49									8	45	81	85	78	80	80	74	531	10,84	1,35
2010	58										16	47	56	79	82	96	79	455	7,84	1,12
2011	68											15	43	81	127	117	125	508	7,47	1,25
2012	58												7	34	84	74	77	276	4,76	0,95
2013	60													15	73	106	119	313	5,22	1,30
2014	96														27	87	143	257	2,68	0,89
2015	67															25	123	148	2,21	1,10
2016	96																32	32	0,33	0,33
TOTAL	**1 001**	**0**	**5**	**31**	**60**	**130**	**211**	**281**	**410**	**491**	**544**	**752**	**697**	**950**	**1040**	**1152**	**1440**	**8194**	**8,19**	

Note: This table must be read in conjunction with Table 10.33.

Source: Clarivate Analytics™ Web of Science™

As indicated earlier, citation values need to be corrected for differences in research fields. The 'mean normalised citation score' (MNCS) is such a normalised indicator. An analysis of the MNCS-values for SADC-ExSA water research publications is presented in Table 8.6, with the annual distribution of the MNCS presented in Figure 8.16. As reference, the MNCS-values of South African water research, which was calculated in the previous chapter 9 (section 9.3.1), is also presented in Figure 8.16. A MNCS-value of 1 means that the citation impact of a specific set of publications (i.e. SADC-ExSA publications) are generating citation rates equal to the world average for publications in that field.

The MNCS-values for water research publications which emanated from SADC-ExSA universities and research institutions, have consistently been below 1, with sharp annual variances observed before the turn of the century. Given the very low annual number of publications during this period, this can be attributed to individual (and few) publications being visible to the science community. Following the turn of the century, SADC-ExSA water research publications remained less visible than the global average, but with an increasing trend. When compared with South African water research, where the increased production has not lead to an increase in visibility, it is clear that water research from SADC-ExSA countries, although at more-or-less the same level, are on an upward trend and becoming more visible.

Table 10.35: Mean normalised citation scores (MNCS) of SADC-ExSA water research publications (1980–2016)

Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Number of publications	4	3	2	2	2	4	4	7	6	3	18	5	5	7	8	8	9	8	7	18
MNCS	1,2496	0,3236	0,0000	0,0000	0,0000	0,6878	0,6506	0,5154	0,1996	0,7697	0,3715	0,1623	0,2441	0,2428	0,1524	0,8704	0,7955	0,1944	0,1524	0,8010

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Number of publications	16	11	24	63	55	58	66	71	60	47	58	74	54	53	95	63	95
MNCS	0,6299	0,4881	0,6618	0,4377	0,5885	0,5546	0,6425	0,4641	0,5004	0,7054	0,4698	0,5033	0,5278	0,7918	0,5799	0,8543	0,6495

Note: The number of publications in Table 8.6 are fewer than the number of publications in Table 10.33 and Table 10.34, as the calculation of the MNCS only consider the number of articles, letters and reviews, whereas Table 10.33 and Table 10.34 present all document types.

Source: Clarivate Analytics™ Web of Science™ and calculated by the CREST

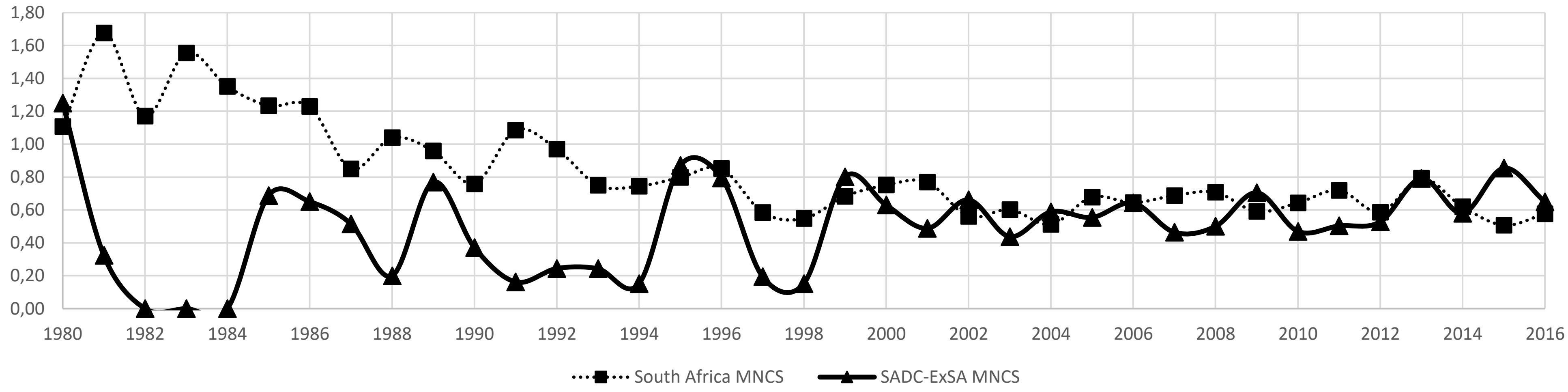


Figure 10.27: Distribution of the MNCS of SADC-ExSA and South African water research (1980–2016)

Source: Clarivate Analytics™ Web of Science™

To conclude this section, it is evident that water research in SADC-ExSA countries, has been cited continuously by the science community with the increase of publications since the turn of the century as researchers have gained access to many more articles than before. Most articles from SADC-ExSA countries have been cited between 1 and 10 times during their lifetime, along with a clear indication that articles published between 2003 and 2009 are being cited more regularly, which coincides with the implementation period of the WARFSA and initial years of the annual WaterNet/WARFSA/GWP SA symposium. This dissemination of research further contribute towards research being more visible globally, and contributes towards the impact of water research emanating from the SADC-ExSA countries. There are further a limited number of articles that have been cited regularly over the years, along with a number of recent articles that have caught the attention of scientists, and which were published in notable journals.

This leads us to the next section, which reports on an analysis that was undertaken to determine the journal profiles in which researchers from SADC-ExSA countries prefer to publish their water research.

10.4 Distribution of SADC-ExSA water research articles by journal

Within the science community, it is important for researchers to publish their work in peer-reviewed journals, as this provide for the thorough examination of research findings by other scientists. Even though the shortcomings of peer reviewing is well documented (Weller, 2001), and although the challenges relating to the rise of predatory journals[41] are evident (Bohannon, 2013; Gasparyan et al., 2015; Mouton & Valentine, 2017; Švab & Makivić, 2015), the publishing of articles in accredited peer-reviewed journals is still regarded as an integral part of the science process. Moreover, article and citation data of articles that are published in well-established journals, and which adhere to principles of rigorous peer reviewing, are captured in citation databases. In the case of the Clarivate Analytics™ InCites™ JCR, citation data from approximately 12 000 journals and conference proceedings from over 3 000 publishers are analysed and presented in an online module (Clarivate Analytics, 2017). In terms of this study, citation data from water research articles between 1980 and 2016 were analysed to determine the top 10 journals (by total number of articles) in which researchers from the SADC-ExSA countries have published. The results are presented in Table 10.36. In addition, the ranking of each journal is presented, with the ranking calculated by a metric namely the JIF and total citations of the journals obtained from the Clarivate Analytics™ InCites™ JCR.

[41] Predatory journals often lack active editorial boards, prioritise financial profit and lack adequate peer-review procedures (Clark & Thompson, 2017; Pickler et al., 2015).

An analysis of the records indicated that there is a preference for researchers from SADC-ExSA countries to publish water research articles in the journal *Physics and Chemistry of the Earth (PCE)*, which was ranked between 38th and 55th amongst journals between 2012 and 2016 (Table 10.36). Between 1980 and 2016, about one in three water research articles published in the SADC-ExSA countries were published in the journal *PCE*. This is substantial, given that the journal was created in 2002, following the merger of *Physics and Chemistry of the Earth Parts A, B and C,* thus attracting a very large number of articles in a relatively short time. This high number of articles can be explained by the close relationship the journal has with the annual WaterNet/WARFSA/GWP SA symposium, where a special edition is published annually linked to conference proceedings. With the symposium attracting very large numbers of water researchers annually, as discussed earlier (see 6.3.1), it is clear that researchers from SADC-ExSA countries are successful in publishing in the *PCE* journal. Water researchers from SADC-ExSA countries further publish in the South African journal *Water SA* (ranked between 57th and 69th between 2012 and 2016), with 5,75% of articles published in this journal (Table 10.36). In recent years, researchers from SADC-ExSA countries further published in journals that were ranked amongst the top 10 journals globally. These journals are the *Journal of Hydrology* and *Catena* and *Agricultural Water Management*, with almost 11% of SADC-ExSA water research articles published in these journals. The top 10 journals comprised 60% of all articles, with the remaining 488 journals comprising 40% of all SADC-ExSA articles.

Table 10.36: Top 10 water research journals in SADC-ExSA countries (1980–2016)

	Source titles	Number of articles	% of articles	Journal rank				
				2016	2015	2014	2013	2012
1	Physics and Chemistry of the Earth	373	30,65%	55/88	47/85	38/83	38/81	47/80
2	Water SA	70	5,75%	66/88	62/85	69/83	61/81	57/80
3	Agricultural Water Management	60	4,93%	14/88	10/85	16/83	18/81	15/80
4	Journal of Hydrology	44	3,62%	6/88	6/85	7/83	10/81	5/80
5	Ocean Coastal Management	42	3,45%	32/88	31/85	28/83	27/81	33/80
6	Water Science and Technology	39	3,20%	61/88	54/85	52/83	44/81	44/80
7	Hydrological Sciences Journal (Journal Des Sciences Hydrologiques)	31	2,55%	24/88	16/85	36/83	39/81	43/80
8	Catena	29	2,38%	8/88	9/85	8/83	15/81	25/80
9	Aquatic Ecosystem & Health Management	23	1,89%	84/105	96/104	69/103	62/103	75/100
10	Journal of Water Sanitation and Hygiene for Development	18	1,48%	72/88	65/85	73/83	71/81	NULL
	Other journals	488	40,10%					

Source: Clarivate Analytics™ Web of Science™ and InCites™; Journal Citation Report®

It is worthwhile to review the full effect the annual WaterNet/WARFSA/GWP SA symposium has on water science in the SADC region. The event, which has become a key annual event in the SADC region since 2000 for water researchers to present their research, rotates amongst the SADC countries, and has attracted approximately 400 delegates at recent events (WaterNet, 2016b). An analysis of the bibliometric data of conference proceedings for water research articles emanating from SADC-ExSA countries between 1980 and 2016 indicate that 108 conference titles were recorded (Table 10.37). By grouping the number of articles associated with the annual WaterNet/WARFSA/GWP SA symposia, it becomes evident that 60% of all articles originated from this annual event.

Table 10.37: Distribution of SADC-Ex SA water research at conferences (1980–2016)

Conference titles	Number of articles	% on conferences
WaterNet/WARFSA/GWP SA Symposia	275	60%
Other symposia (107 conference titles)	187	40%
Total	462	

As mentioned at the beginning of the chapter (10.1), the annual WaterNet/WARFSA/GWP SA symposium has an agreement with the *PCE* journal, to publish proceedings of the symposia annually in special issues. In 2007, Van der Zaag assessed the qualitative and quantitative contribution articles from the annual symposium made to five special issues of the journal *PCE,* at that stage (Van der Zaag, 2007). He found that the contributions have made a significant contribution to water research publications not only in the region, but also in the African water sector (for more detail on the findings of the study, please see section 3.2.1).

To identify further how the publication of water research articles in the journals changed over time, the annual distribution is presented in Figure 10.28 and Figure 10.29. For clarity, the top 10 journals are presented in two figures, with Figure 10.28 presenting the annual number of articles in the top five journals, and Figure 10.29 presenting the annual number of articles in journals ranked 6 to 10.

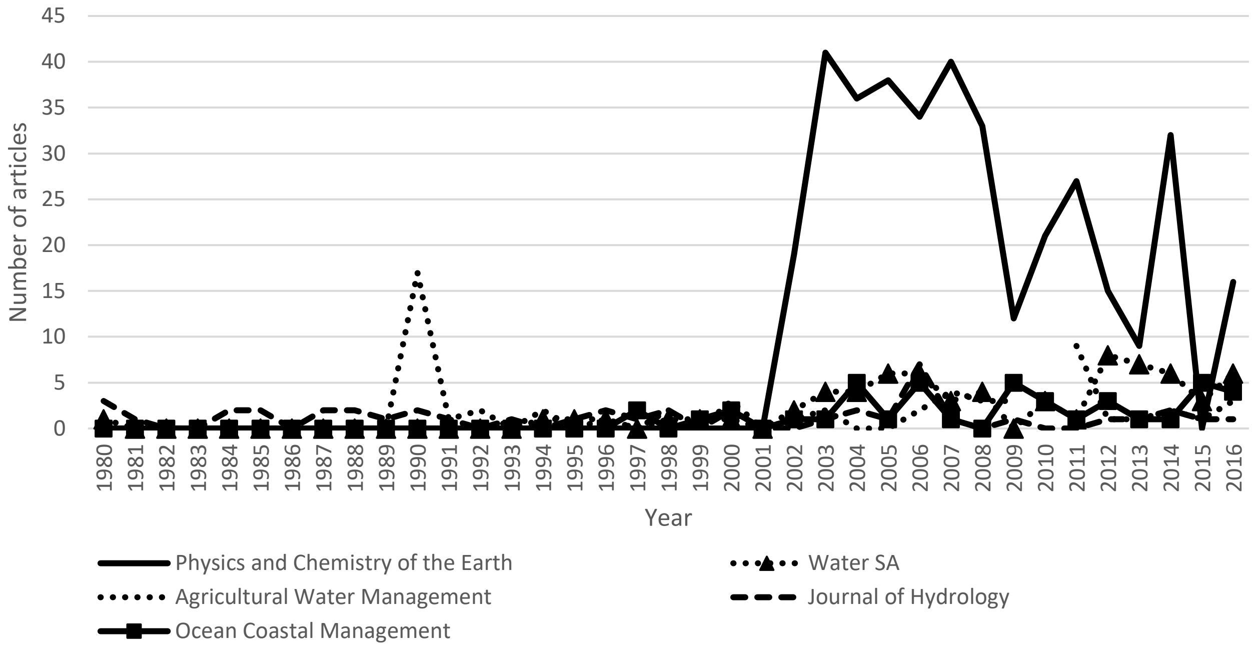


Figure 10.28: Annual distribution of SADC-ExSA research articles between 1980 and 2016: Top 1–5 journals

Source: Clarivate Analytics™ Web of Science™

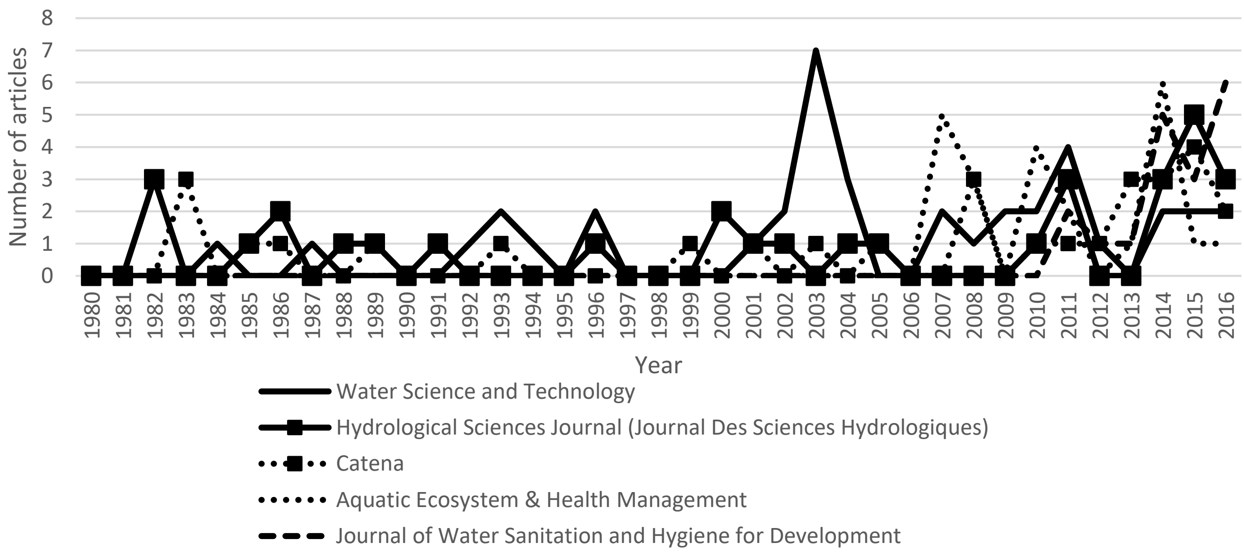


Figure 10.29: Annual distribution of SADC-ExSA water research articles between 1980 and 2016: Top 6–10 journals

Source: Clarivate Analytics™ Web of Science™

The significant number of articles published in the *PCE* journal, when compared with other journals, becomes evident, especially between 2003 and 2008 (Figure 10.28). As indicated earlier, this period coincides with the implementation period of the WARFSA programme, and it is interesting to note the decline in articles in the *PCE* journal following the end of the implementation period of the WARFSA programme. In recent years, water researchers from

SADC-ExSA countries have increased their articles in other journals, such as *Water SA* (Figure 10.28) and *Aquatics Ecosystem Health & Management*, the *Journal of Water, Sanitation and Hygiene for Development* and *Catena* (Figure 10.29).

It is evident from this section that, although water research from SADC-ExSA countries is published in some of the highest-ranking journals globally, there is a very strong preference to publish in the journal *Physics and Chemistry of the Earth.* This can be attributed to the association of the journal with the annual WaterNet/WARFSA/GWP SA symposium, which attracts a large number of water researchers from especially SADC-ExSA countries annually. It is further known that the Dutch government, along with researchers from the Delft–UT supports this symposium, along with the WaterNet master's degree programme, which leads us to the following section.

In the previous chapter, the institutional support for South African water research was presented (see 9.5), where it was found that local research funding agencies, such as the NRF and the WRC were acknowledged significantly more as funding agency in research articles, when compared to international support. In the next section, the agencies and institutional support for water research in SADC-ExSA countries will be investigated, with the objective to determine from where the predominant support for water research is obtained.

10.5 Support for water research in the SADC-ExSA countries

As established in Chapter 6 of this thesis, there are various programmes and network initiatives, such as WaterNet, the AU/NEPAD Southern African Network of Water Centres of Excellence, the Applied Centre for Climate & Earth Systems Science (ACCESS) and the Southern African Science Service Centre for Climate Change and Adaptive Land Management (SASSCAL) supporting water research in the SADC region. In addition, various international organisations such as the Global Water Partnership (GWP), the United Nations Educational, Scientific and Cultural Organization (UNESCO), the International Water Management Institute (IWMI) along with the International Water Association (IWA) and Cap-Net, support research and human capacity development in the SADC water sector. Moreover, increasingly, South African institutions such as the Water Research Commission (WRC), the Water Institute of Southern Africa (WISA) and the South African Young Water Professionals (YWP-ZA), find themselves supporting not only South African research and capacity activities, but also research in the larger SADC region.

With no previous studies undertaken in determining the extent and distribution of support for research in SADC-ExSA countries, it is difficult to determine precise figures. As in the previous chapters, the acknowledgements researchers provide give an indication of funding agencies when publishing their research, and were used for this section. It is further acknowledged that there are limitations to this data, in that researchers often neglect to acknowledge funding sources, unless it is specifically stipulated in a funding agreement. Moreover, as the source of the data is the Clarivate Analytics™ Web of Science™ (WoS), such data have been captured actively since 2008, and different spellings exist for the same institution when bibliometric data are analysed from the WoS, making it difficult to report accurately on exact contributions from organisations. However, given these limitations, and in the absence of other data, the following methodology was used to analyse the data.

An analysis of the 1 217 water research articles published in SADC-ExSA countries between 1980 and 2016 revealed that acknowledgement data were indeed limited to after 2007. However, 56% of all water research published between 1980 and 2016, was published after 2008, and for this reason, funding agency data were restricted to water research articles in the SADC-ExSA countries between 2008 and 2016, which resulted in the analysis of 619 articles. For these articles, 586 funding agency records were extracted and classified according to the following categories:

- Type of funding agency:
  a. research funding agency, such as the Austrian Science Fund or the Swedish International Development Cooperation Agency (Sida);
  b. university or research institute, typically based at a university in the SADC-ExSA countries;
  c. a government department;
  d. private industry;
  e. other – a small percentage of institutions could not be classified, and were therefore grouped as ‘other’ (4,9%), as insufficient information was available in terms of the records.
- Geographical location:
  e. Local within the SADC region: research funding agencies, universities/research Institutes, government ministries and departments, and private industry. In addition, in order to provide a better indication of South African support versus the rest of the SADC region, data for the local research funding agencies and university/research institutes were further divided indicating the portion of South African agencies and universities/research institutions versus the rest of SADC.
  f. International research funding agencies, universities/research institutes and government ministries and departments.

The results of the categorisation are presented in Table 10.38 and Figure 10.30. For comparison, the percentage of total acknowledgements for South African water research is presented in Table 10.38, as was calculated in Chapter 9.

Table 10.38: SADC-ExSA water research funding institutions by type

Type of funding organisation	Geographical location	Count	% of total acknowledgements	% of total acknowledgements (South Africa) (refer to Chapter 9)
Research funding agency	Local	30	5,1%	40,0%
Research funding agency	*South Africa*	*17*	*2,9%*	*38,4%*
	SADC-ExSA	*13*	*2,2%*	*1,6%*
Research funding agency	International	*301*	*51,4%*	*16,1%*
University/Research institute	Local	47	8,0%	17,6%
University/Research institute	*South Africa*	*16*	*2,7%*	*17,1%*
	SADC-ExSA	*31*	*5,3%*	*0,6%*
University/Research institute	International	76	13,0%	4,8%
Government	Local	34	5,8%	7,1%
Government	International	48	8,2%	3,8%
Private industry	Local	5	0,9%	5,1%
Private industry	International	16	2,7%	2,3%
Other		29	4,9%	3,2%
TOTAL		586	100%	100%

Note: Funding agency records were limited to between 2008 and 2016, as Clarivate Analytics™ Web of Science™ started capturing such data actively only in 2008.

Source: Clarivate Analytics™ Web of Science™

Should one take the acknowledgement of funding agencies in articles as an indication of the support for research, the complete dominance of international funding support for water research in SADC-ExSA countries is evident, as depicted in Table 10.38 and Figure 10.30. This is in contrast to South Africa where water research is predominantly funded through South African funding mechanisms. In the SADC-ExSA countries, international funding comprises 75% of all acknowledgements, with 20% acknowledgements for local SADC funding mechanisms while 5% of funding sources could not be categorised due to a lack of information. In contrast, in South Africa, 27% of acknowledgements were made in terms of international funding agencies.

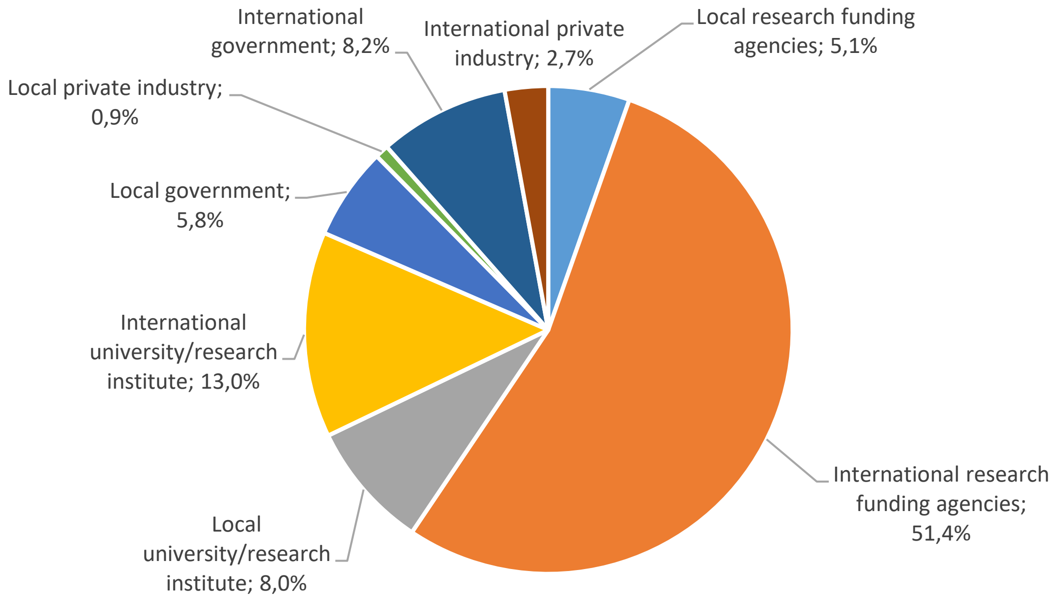


Figure 10.30: SADC-ExSA vs. International funding mechanisms for SADC-ExSA water research (2008–2016)

Source: Clarivate Analytics™ Web of Science™

Detail of the funding support indicates that 51,4% of funding came from international funding agencies, such as the Swedish International Development Cooperation Agency (Sida), the European Commission, the European Union, the European Community, and the International Foundation for Science (IFS), as presented in Table 10.38 and Figure 10.30. This is followed by International universities or research institutes and international governments, which have been acknowledged 13% and 8% as funding institutions respectively. These international funding mechanisms are followed by local universities or research institutions and governments in SADC-ExSA countries, which were acknowledged 8% and 5,8% of the time, while local funding agencies, such as the National Research Fund of Mozambique and the Malawi National Research Council, acknowledged 5% of the time. In comparison, South African research finding agencies were the major contributor, being acknowledged 38,40% in research articles.

South African research funding agencies and universities further contributed to research in SADC-ExSA countries, and were acknowledged 2,9% and 2,7% times, with international and SADC private industry probably underreported at 2,7% and 2,2% (Table 10.38). It can be argued that private industry is probably underreported, as the contribution by private industries would rather reflect as patents and not as peer-reviewed articles, given the financial focus and value of patents. These acknowledgements will therefore not necessarily reflect accurately in this analysis.

From this section, the complete reliance by SADC-ExSA countries for foreign support for water research becomes evident. To a limited extent, funding mechanisms exist in the SADC-ExSA countries, but they are extremely limited. Some funding support does spill over to the SADC-ExSA countries from South Africa, but it is evident that this is limited.

10.6 Summary and conclusion

Given the dominance of South African water research in the SADC region in terms of research output, this chapter analysed the water research production from SADC countries, where South African research output was excluded. A bibliometric analysis of these SADC-ExSA countries revealed that:

1. The share of SADC-ExSA countries in terms of African water research has in general increased, albeit marginally, since the early 1980s to the end of the 1990s, after which it stabilised at around 10%.
2. Since the turn of the century, water research from SADC-ExSA countries has increased, with a notable prolonged increase between 2002 and 2006, after which the water research output of the SADC-ExSA countries dramatically increased to a high of 20,5% in 2006 (from 10% in 2002) of Africa's share of water research publications.
3. Water research in SADC-ExSA countries predominantly focussed on the **modelling** of **water systems**, and the **management** aspects with keywords including **conservation**, **Southern Africa**, **Africa**, **climate change**, **rainfall**, **systems**, **Zimbabwe** and **river-basin**. Other dominant research areas are **river systems**, **groundwater quality**, **climate** with links to **variability**, **rainfall** and **impact**.
4. Countries such as Zimbabwe, Tanzania, Botswana, Malawi and Namibia are among the top SADC-ExSA countries in terms of water research output.
5. Moreover, several SADC-ExSA countries have increased their water research output since the turn of the century, such as Botswana, Lesotho, Madagascar, Malawi, Mozambique, Namibia, Swaziland, Tanzania, Zambia and Zimbabwe, with countries such as Malawi, Tanzania and Zimbabwe significantly increasing their water research output. It is further well known that UZ and the UDSM are major universities in the WaterNet master's degree programme in Integrated Water Resource Management (IWRM).
6. In SADC-ExSA countries, 77% of all water researchers have published one article, accounting for 2 086 authors. The number of authors who have published two articles

declines to 12% (or 333 authors), followed by less than 5% (or 117) authors, publishing three articles. There were 24 authors who have published more than 10 articles.

7. The 24 researchers in the SADC-ExSA countries who have published more than 10 articles, were from the University of Zimbabwe (UZ), Chinhoyi University of Technology (CUT) in Zimbabwe, Delft University of Technology (Delft–UT) in the Netherlands, the University of Botswana (UB) (Botswana), University of Dar es Salaam (UDSM) (Tanzania), Eduardo Mondlane University (UEM) (Mozambique), the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) (Zimbabwe), the Polytechnic Namibia (now known as the Namibia University of Science and Technology), and the University of Malawi (UNIMA) (Malawi). There are more universities and research institutions beyond the SADC-ExSA countries, such as the University of Cape Town (UCT), the University of the Western Cape (UWC), the University of the Witwatersrand (WITS) and the University of KwaZulu-Natal (UKZN), all in South Africa, that have published articles with researchers in SADC-ExSA countries. The relative large presence of water researchers from the Netherlands, is further noteworthy.

8. The researchers who have received the highest average citations per articles are Dr Rockstrom from Stockholm University, Prof. Wolski from the University of Botswana, Prof. Savenije from the Delft–UT in the Netherlands, and Dr Twomlow from ICRISAT in Zimbabwe.

9. It is further evident that many of the researchers who publish the most articles in the SADC-ExSA region, can be associated with at least one publication from the WARFSA-programme.

10. Strong co-article networks exist amongst the top researchers, often not limited to researchers in a single institution, as in the case of South African top researchers, but with researchers from different institutions in broader networks. It is further known that these researchers are members of WaterNet, the largest network of water researchers in the SADC region.

11. Four out of five articles had multiple authors, with most articles having three authors.

12. Single-authored articles have declined since the turn of the century, to around 5% of all water research articles in recent years.

13. Since 2009, articles with more than five authors have been the predominant type of article, ranging between 34% and 37% of water research publications annually. Following an initial increase in articles with two authors, these articles have remained constant, comprising 16% of all water research articles in 2016.

14. Countries such as Tanzania, Namibia, Madagascar, Lesotho, the Democratic Republic of Congo and Angola tend to co-publish more within the SADC region and beyond SADC, than in their own countries. Data from the Democratic Republic of Congo and Angola should be interpreted with caution, as few water research articles had been published from these countries.

15. In the SADC region, the most predominant countries, which co-publish with other countries are Zimbabwe, Tanzania, Botswana, South Africa, Malawi, Namibia, Mauritius, Mozambique, Swaziland and Zambia. Countries beyond SADC are Belgium, the United Kingdom (England), France, Germany, Netherlands, Norway Sweden (in Europe), the United States (North America) and Australia (Australasia). Water researchers from Kenya are the only other researchers from an African country who have published more than 20 articles within SADC-ExSA countries.

16. It is evident that relatively strong water research associations exist between:
    a. Zimbabwe and South Africa, the Netherlands and Sweden;
    b. Tanzania and countries such as the Netherlands, Kenya, Belgium, Sweden, Germany, the United Kingdom (England) and South Africa;
    c. Botswana and South Africa, the United States, the United Kingdom (England) and Malawi; and
    d. Namibia, which has a strong association with South Africa.

17. It is further evident that most water researchers in SADC-ExSA countries collaborate with other scientists in the same country (national collaborations) with the exception being Angola, the DRC, Madagascar and Namibia, where researchers have co-authored articles with researchers from outside their countries.

18. Given the large number of research outputs from the SADC region by South African researchers, it is probably not surprising that South African researchers feature as collaborators in most SADC countries. The exceptions are Mozambique, and to some extent Zambia, where Zimbabwe and Botswana feature more often as SADC collaborators.

19. In terms of the citation of water research from SADC-ExSA countries, it is evident that 25% of water research published by SADC-Ex-SA institutions has never been cited, which is normal, as not all publications are always cited. It is further evident that just over half of all publications (52%) have been cited between one and ten times, at an average citation rate of 4,11 per article.

20. It is evident that the annual number of publications has gradually increased over the years, from 46 in 1980 to a point in 2001 where the number of publications increased to above 150 for the first time. These publications were increasingly cited, along with

the gradual increase in publications. After 2001, the total number of water research publications declined slightly to 112 publications in 2005, after which it gradually increased to 268 publications in 2016. During this time, after the turn of the century, the average annual citation rate remained constant between 1,49 in 2003 and 8,89 (in 2006), and only continuously declining since 2013 – this can be attributed to the time lag it takes between the publication of articles, and the citation of these articles.

21. Based on the calculation of the mean normalised citation score (MNCS) of SADC-ExSA water research, the MNCS-score have consistently been below 1, with sharp annual variances observed before the turn of the century - a MNCS-value of 1 means that the citation impact of a specific set of publications are generating citation rates equal to the world average for publications in that field. Given the very low annual number of publications during this period, this can be attributed to individual (and few) publications being visible to the science community. Following the turn of the century, SADC-ExSA water research publications remained less visible than the global average, but with an increasing trend. When compared with South African water research, where the increased production has not lead to an increase in visibility, it is clear that water research from SADC-ExSA countries, although at more-or-less the same level, are on an upward trend and becoming more visible.

22. There are 15 articles, which have been cited between 5 and 10 times on average per year, and three articles, which have been cited, on average, between 11 and 15 times per year. No articles with an average annual citation rate of more than 16 per year have been reported. Of the three articles with an average annual citation rate of between 11 and 15 per year, two were published in 2002 and 2003 respectively. This would suggest that these articles have been of interest to the science community over a long period.

23. It is evident that, although water research from SADC-ExSA countries is published in some of the highest-ranking journals globally (11% of all articles), there is a very strong preference to publish in the journal *Physics and Chemistry of the Earth,* with 31% of all water research published from SADC-ExSA countries, being published in this journal. This can be attributed to the association of the journal with the annual WaterNet/WARFSA/GWP SA symposium, which attracts a large number of water researchers from SADC-ExSA countries annually. It is further known that the Dutch government, along with researchers from the Delft University of Technology supports this symposium, along with the WaterNet master’s degree programme, which leads us to the next point.

24. In terms of conferences, 60% of all articles originated from the annual WaterNet/WARFSA/GWP SA symposia, which have been rotating between SADC countries since 2000, and annually attract approximately 400 delegates.

25. Finally, SADC-ExSA countries are heavily reliant on foreign support for water research, as 75% of all acknowledgements for funding support in articles, are for international funding institutions. Funding mechanisms exist in the SADC-ExSA countries, but they are extremely limited.

26. International and SADC private industry is probably underreported at 2,7% and 2,2% of acknowledgements. Given that private industry rather focusses on patents as research outputs due to the financial value of patents, these acknowledgements are thus not necessarily accurately reflected in this analysis.

From part B of this thesis, it becomes evident that the SADC water sector is a case of two halves. On the one hand, the SADC water sector is dominated by water research output from South African universities and research institutions with 81% of water research conducted since 1980 originating from South African researchers. Moreover, water research in South Africa is supported by a research system, which is robust with the majority support from in-country funding mechanisms, such as the WRC and the NRF. South African water researchers further tend to co-publish to a large extent with researchers from South Africa, then beyond SADC, before they co-publish with researchers from the SADC region.

On the other hand, the universities and research institutions from the rest of the 14 member states within the SADC region, have collectively produced less than 20% of the water research during the period 1980–2016. In addition, these researchers are heavily dependent on outside funding for water research. Since the turn of the century, there has, however, been much progress in developing water research in these SADC-ExSA countries, especially with the introduction of the WaterNet master's degree programme and the annual WaterNet/WARFSA/GWP SA symposium, along with the initial implementation of the WARFSA programme in the early 2000s. In the next chapter, the focus is specifically on the WARFSA programme, with the objective to analyse knowledge produced in research projects associated with the WARFSA.

PART C

Case study: An Analysis of Knowledge Production and Policy-/Practitioner Aspects of the Water Research Fund for Southern Africa (WARFSA)

In Part C of this study, the WARFSA-funded research projects will be assessed, in order to determine better understand what scientific knowledge was produced (chapter 11), and further, what policy-/practitioner aspects can be derived from the projects (chapter 12).

Chapter 11

AN ANALYSIS OF KNOWLEDGE PRODUCED IN RESEARCH PROJECTS ASSOCIATED WITH THE WATER RESEARCH FUND OF SOUTHERN AFRICA (1999–2016)

11.1 Introduction

As was shown in previous chapters, bibliometric analyses of water research articles in the SADC region highlight the significant increase in water research articles, especially in countries excluding South Africa (SADC-ExSA countries), between 2002 and 2008 (Figure 11.1). This period coincides with the implementation period of Phases I and II of the Water Research Fund for Southern Africa (WARFSA), the early years of the annual WaterNet/WARFSA/GWP SA symposium and the WaterNet master's degree programme in Integrated Water Resource Management (IWRM). Notably, the symposium was launched with the initial objective to be the scientific platform for water researchers in the SADC region, and specifically researchers in the WARFSA and WaterNet master's degree programmes, to present and disseminate their research (see Wright, Savenije & Van der Zaag, 2001).

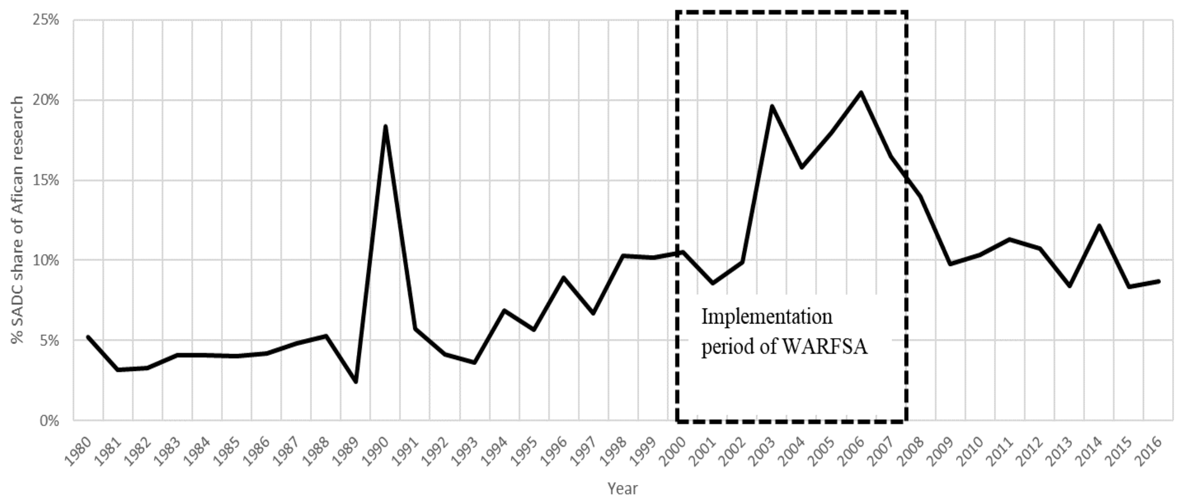


Figure 11.1: WARFSA implementation period in relation to water research output from SADC-ExSA countries as a share of Africa

Source: Clarivate Analytics™ Web of Science™

The purpose of this chapter is to report on an analysis of the 78 research projects associated with Phases I and II of the WARFSA programme to understand the knowledge produced from WARFSA-funded research better. Refer to Annexure C for a list of WARFSA-funded research projects, which was used for this study.

To contextualise this chapter further within the HERG Payback Framework used as a conceptual framework for this study, Figure 11.2 presents the stage where the primary outputs are created (stage 3), which is followed by the dissemination interface. In the context if this chapter, the citation data from the research outputs emanating from the 78 research projects associated with the WARFSA programme were analysed, in conjunction with the subsequent dissemination of the research in scientific journals. These research outputs were produced by various researchers from the SADC water sector, and institutions as presented in preceding chapters of this study.

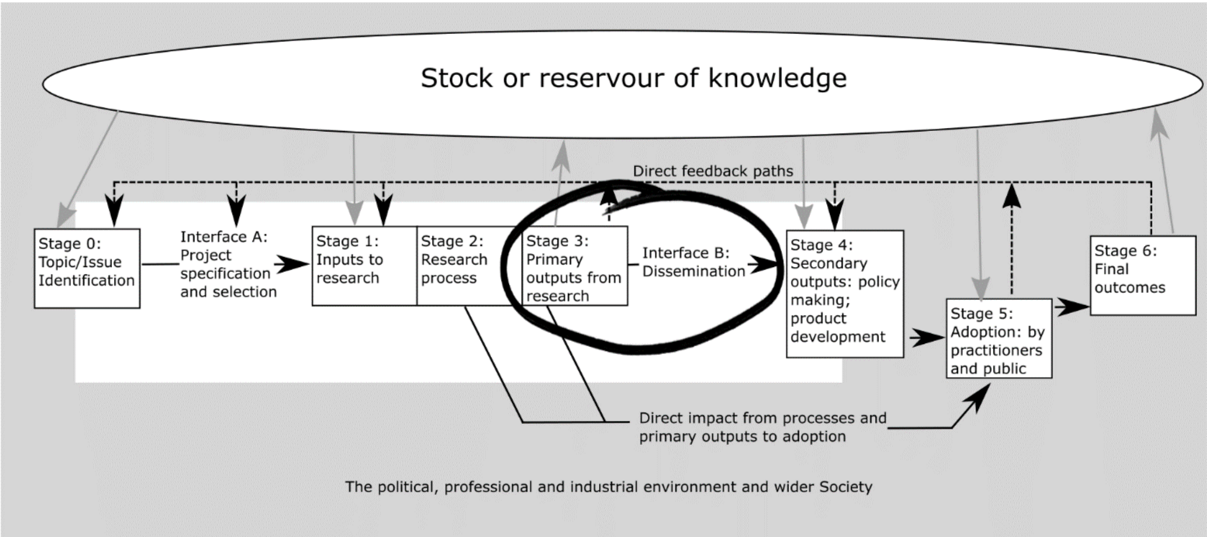


Figure 11.2: The primary output stage and dissemination interface in the HERG Payback Framework

Source: Adapted from Hanney et al. (2004)

It is further important to acknowledge the contribution the WaterNet master's degree programme in IWRM has made towards water research in the SADC region, with the establishment of the programme well documented (Van der Zaag, 2005; Wright et al., 2001). To get some sense of the contribution, it is worth considering that in the period 2000–2015, the programme has trained 427 graduates from the SADC region, of whom 34% were women (Kileshye-Onema, 2014; Waternet, 2016c). This study, however, focussed on the 78 research projects associated with the WARFSA programme.

The study conducted by Van der Zaag (2007) should also be noted. In his study, Van der Zaag analysed the qualitative and quantitative contribution of the WaterNet/WARFSA/GWP SA symposium papers, and further the WaterNet/WARFSA/GWP SA symposium papers published in five special issues (2002–2006) of the scientific journal, *Physics and Chemistry of the Earth (PCE)*, which is linked to the symposium. Given the implementation period of the WARFSA programme, this would have coincided with the timeframe of Van der Zaag's (2007) study. The present study contributes to the Van der Zaag (2007) study, in that the total extent of research outputs was examined, beyond those published in the 2002–2006 special issues of the *PCE* journal. Moreover, the period of this study was extended to between 1999 and 2016, as some research outputs were produced after the conclusion of the WARFSA programme in 2007. For a detailed discussion on the major findings of the Van der Zaag (2007) study, see section 3.2.1.

By making use of webometric and bibliometric data analysis techniques, this chapter will reflect answers to the following questions:

1. Which types of research outputs were produced through the WARFSA programme?
2. How many WARFSA-related outputs where captured in international citation databases, such as Web of Science and Scopus, and how many of the research outputs are only available on the Internet?
3. Regarding these outputs captured in international citation databases –
   a. What were the publication trends?
   b. What were the citation trends?
   c. What was the global geographical footprint of WARFSA-related articles being cited?
   d. To which institutions were researchers who published peer-reviewed articles from the WARFSA programme affiliated?

Before the bibliometric study of WARFSA-funded research can be reported, a brief overview of the programme is presented, to provide context for the study.

11.2 Background to the WARFSA

Within the Southern African region, the WARFSA initiative was conceived at a regional planning workshop in 1998, and established in 1999 with the purpose of building research capacity among regional institutions and individuals, with a focus in Integrated Water Resource Management (IWRM) in the sub-region (Van der Zaag, 2005; Wright et al., 2001). WARFSA Phases I and II were administered by the Institute of Water and Sanitation Development (IWSD) in Zimbabwe, and donor-funded by the Swedish International Development Agency (Sida) and to a lesser extent, the Danish International Development Agency (DANIDA). Phase I of the WARFSA Programme concluded in 2002 while Phase II concluded in 2007. Research funding from the WARFSA programme was awarded on a competitive basis, and evaluated through a scientific committee for approval by the WARFSA board.

Apart from the programme evaluations (IWSD, 2005; Krugmann, 2002), and a bibliometric study undertaken by Van der Zaag (2007), an evaluation of the scientific knowledge produced by the WARFSA specifically, was never undertaken.

11.3 Results and discussions

From the outset of this part of the study, it became evident that the analysis of knowledge produced from research funded in the WARFSA programme, would be a study comprising two parts. On the one hand, quite a number of research outputs were identified, and these assisted in identifying the extent of research outputs, which emanated from the WARFSA-funded research projects. In all research outputs, basic information such as the WARFSA project, the title, author(s) and type of output could be determined. On the other hand, a few research outputs were published in peer-reviewed journals, from where citation data could be extracted. The discussion will thus initially present the analysis of all research output, which is followed by the bibliometric analysis of the articles published in peer-reviewed journals as captured in the Clarivate Analytics™ Web of Science™.

In the next section, the research produced under the WARFSA programme is presented, referring to research outputs such as articles published in scientific journals, conference presentations, books, book chapters and research reports. Data relating to these products are often stored in reference databases. In addition, graduate students are considered knowledge products, and are often associated with research projects as they participate in and complete masters and PhD research projects. Within a research project, details of such students are often captured in research project reports, or as in the case of the WARFSA programme, information was presented in reports to the WARFSA board.

Based on the available information, at least 230 research outputs were produced from the WARFSA programme, which comprise articles in scientific journals, conference proceedings, BSc, MPhil, MSc, MA and PhD dissertations, technical reports, book chapters and policy documents (Table 11.1). Articles published in scientific journals (44%) and conference proceedings (43%) constitute the majority of output. Note that the same research outputs could have been presented as conference proceedings, and not necessarily disseminated as articles in journals. In addition, 75 (33%) post-graduate degrees in the form of PhD and master's degrees resulted from research projects associated with the WARFSA programme. A few technical reports (6%), book chapters (3%) and policy documents (2%), which emanated from the study, could be identified. The number of technical reports is probably underreported. This is due to the time that passed following the conclusion of the WARFSA programme in 2007, and when the present study was undertaken in 2014 to 2016, creating challenges in accessing technical reports, even though all research projects would have regularly produced technical reports of the projects.

Table 11.1: Number of WARFSA-related knowledge outputs by type (2000–2016)

Knowledge and innovation type	Count	% of 230
Scientific journal articles	102	44%
Conference proceedings	99	43%
BSc, MPhil, MSc, MA, PhD	75	33%
Technical reports	14	6%
Book chapters	9	4%
Policy document	5	2%

11.3.1 Publication trends

Research outputs were disseminated through various media, such as peer-reviewed journals or online web portals. Almost 30% of all research outputs were published in the journal *Physics and Chemistry of the Earth (PCE)* alone, and 28,7% of all scientific publications were made available through various online platforms such as Waternetonline.ihe.nl and various university online platforms (Table 11.2). The publication and citation data are not available for the outputs published on the online platforms, apart from that these publications can be downloaded. These outputs are followed by 6,1% of articles published in other scientific journals namely *Water SA, Onderstepoort Journal of Veterinary Research, Aquatic Ecology, Plant Ecology, Transactions of The Royal Society of Tropical Medicine and Hygiene, Journal of Arid Environments, Applied Geochemistry, African Journal of Ecology, Hydrogeology Journal, Bulletin of Environmental Contamination and Toxicology*, *Japanese Journal of Veterinary Research, Environmental Monitoring and Assessment,* and *Water International* journal. In addition, 5,7% of research outputs were presented as proceedings of the WaterNet/WARFSA/GWP SA symposium and never published in a scientific journal. Lastly, about 30% of the research outputs could not be categorised, as summarised meta-data were recorded from WARFSA board meetings reports, and did not contain the detail of these outputs and where they could be accessed.

The close association of the WARFSA programme with the annual WaterNet/WARFSA/GWP SA symposium and the publication in special issues of *PCE* becomes evident in the large number of articles in the journal. Where publications were not published in journals, research outputs were further disseminated online, making the bulk of research outputs accessible.

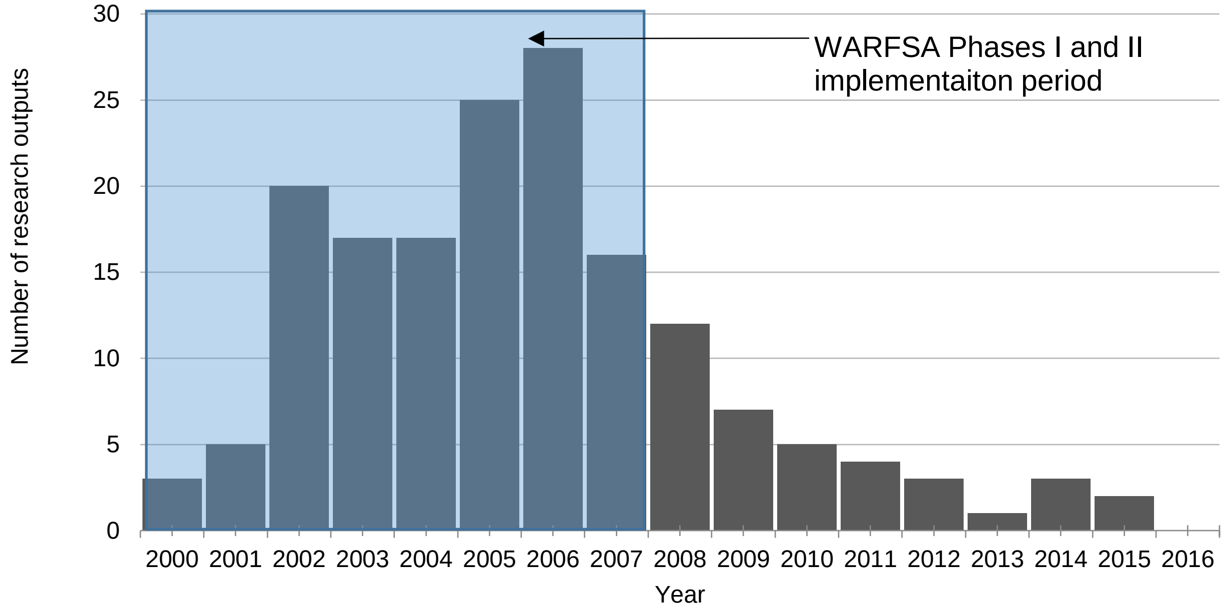
Table 11.2 Availability of WARFSA Phases I and II publications

Publication	Number of publications	As % of ALL research outputs	
Physics and Chemistry of the Earth	68	29,6%	Articles used for publication and citation trend analysis.
Water SA	2	0,9%	
Onderstepoort Journal of Veterinary Research	2	0,9%	
Aquatic Ecology	2	0,9%	
Plant Ecology	1	0,4%	
Transactions of The Royal Society of Tropical Medicine and Hygiene	1	0,4%	
Journal of Arid Environments	1	0,4%	
Applied Geochemistry	1	0,4%	
African Journal of Ecology	1	0,4%	
Hydrogeology Journal	1	0,4%	
Bulletin of Environmental Contamination and Toxicology	1	0,4%	
Japanese Journal of Veterinary Research	1	0,4%	
Environmental Monitoring and Assessment	1	0,4%	
Water International	1	0,4%	
Proceedings of a WaterNet/WARFSA/GWP SA Symposium ONLY	13	5,7%	
Null*	70	30,4%	
Various online platforms	66	28,7%	
Total	**230**	**100,0%**	

* 70 publications were reported in reports, which were not accessible online i.e. dissertations.

Citation data were available for around 30% of the research outputs from the Clarivate Analytics™ Web of Science™ citation database. The articles will be discussed separately later in this chapter (see 11.4.2, 11.4.3 and 11.4.4).

If one further considers the annual distribution of research outputs, a significant number of publications were produced in 2002, following the launch of the WARFSA programme in early 2000s, as reflected in Figure 11.3. During the early stages of the WARFSA programme, some outputs (such as technical reports) emanated, as can be expected as projects were initiated in 2000, with many projects concluding after two years. As can be expected, the bulk (69%) of the research outputs were produced between 2000 and 2006 during the implementation period of the WARFSA programme (Figure 11.3), at an average of 16 outputs per year during this period. Funding for Phases I and II of the WARFSA programme concluded in the mid-2000s, which is reflected in the number of research outputs declining from 2007 to 2016. During this time, 31% of research outputs were produced at an average of six research outputs per year.

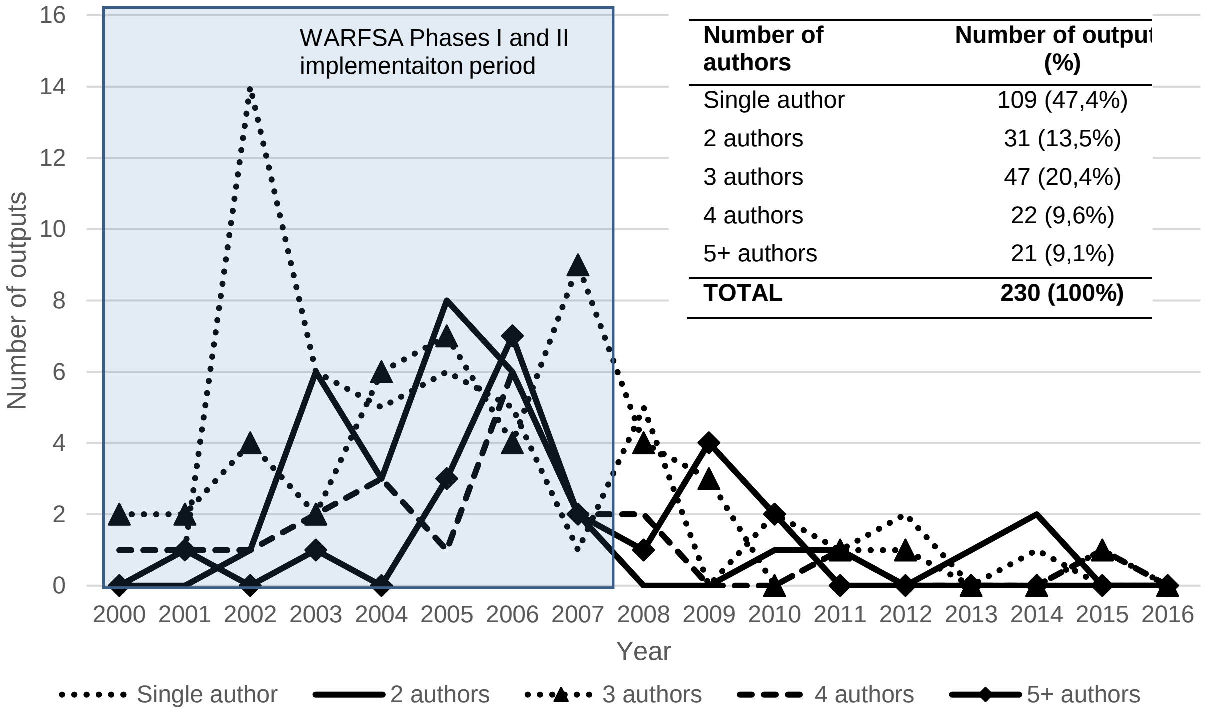


Total: 230 (note that the publishing date of 62 research outputs could not be established)

Figure 11.3: Annual research outputs from the WARFSA programme (all types)

As the WARFSA programme funded research projects, various researchers were involved in the projects. From the research outputs produced, the number of authors per article could be determined. Where a post-graduate dissertation was identified, the number of authors was calculated as a single author. In some cases, the WARFSA programme reports, which were presented to the WARFSA board, contained the title and author of the dissertation, but unfortunately not always the year in which the dissertation was completed. In some cases, an Internet search could identify the graduation year. In total, the publication year for 62 research outputs, which include dissertation, policy document and technical reports, could not be determined. The result of the analysis is presented in Figure 11.4 where it is evident that almost half of all research outputs (47%) were published as articles with a single author or as articles with three authors 20%, two authors 14% and four authors at 10%. In addition, 21 research outputs, comprising 9% of the outputs, were published with five and more authors. Many of the single-authored outputs could be linked to the number of dissertations identified, considering that 33% of the outputs were BSc, MPhil, MSc, MA and PhD dissertations. The majority of outputs were published with multiple authors, in line with the objectives of the programme, as many research projects were funded, which supported interdisciplinary research teams (IWSD, 2005; Krugmann, 2002).

Most of the single-authored research outputs were produced in the early years of the WARFSA programme in 2002 (Figure 11.4). For the duration of the implementation period of the WARFSA programme, multiple-authored research outputs increased, reaching a peak towards the middle of the WARFSA implementation period in 2006/2007. As can be expected, research outputs declined after 2007 when support for the WARFSA programme formally concluded.



Note: The publication date for 62 outputs could not be determined

Figure 11.4: Number of authors per research output of WARFSA-funded research projects

Researchers in the WARFSA programme did tend to publish research outputs with increasing numbers of co-authors as the programme developed over time, with many articles with more than three authors towards the end of the programme in 2006 and 2007.

As indicated earlier in the research methodology chapter (see 5.3.4), limited information was available for the research outputs which were not published in peer-reviewed journals, apart from what is presented above. Our attention now shifts to the 85 articles published in peer-reviewed journals, in order to determine detailed publication and citation trends for these articles.

11.3.2 Citation analysis of WARFSA-funded articles

From the publication and citation analysis, it is evident that articles published in peer-reviewed journals were mostly published between 2003 and 2007, with 85% of articles published during this time (Figure 11.5). In addition, these articles have been cited 1 246 times,[42] with a steady increase in citations since 2005, to 178 citations in 2016 (Figure 11.5). This phenomenon where articles are only cited a few years after their publication, can be attributed to citation lag (Mamtora, Wolstenholme & Haddow, 2013; Smith, 2010). If one were to consider the citation rate for a moment, it is evident that the citation rate for WARFSA-related articles was 0,92 per article (Table 11.3). When the citation rate of WARFSA-related articles is compared with the citation rate of water research in the SADC region and from elsewhere on the African continent, the citation rate of WARFSA-related articles is significantly higher than for articles published in SADC and the African continent during the same period (Table 11.3). In the SADC region, the citation rate was 0,50, South Africa 0,49, SADC countries where South Africa is excluded (SADC-ExSA countries) was 0,51, and African water research was 0,59. This would suggest that water research emanating from WARFSA projects was of more interest to the scientific community. The exact reason for this is unclear, but could be attributed to the establishment of the WaterNet/WARFSA/GWP SA symposium, thus providing a widely attended platform for the dissemination of research – the increased effect of symposium papers highlighted in the Van der Zaag (2007) study.

Table 11.3: Citation rate of WARFSA-funded articles versus SADC regional water research (2002–2016)

	Number of articles	Number of citations	Citation rate
WARFSA articles	85	1 246	0,92
SADC articles	3 557	26 625	0,50
South Africa articles	2 729	19 880	0,49
SADC-ExSA articles	972	8 006	0,51
African articles	8 181	76 980	0,59

Source: Clarivate Analytics™ Web of Science™

Articles published in 2008 and 2009, were on average, cited more often than articles published between 2002 and 2007, and more recently in 2013 (Figure 11.5). One reason for this increased average citation score in 2008, 2009 and 2013, could be ascribed to the possibility that there were articles published during this time, which were of more interest to the scientific community than previous articles.

[42] Include self-citations.

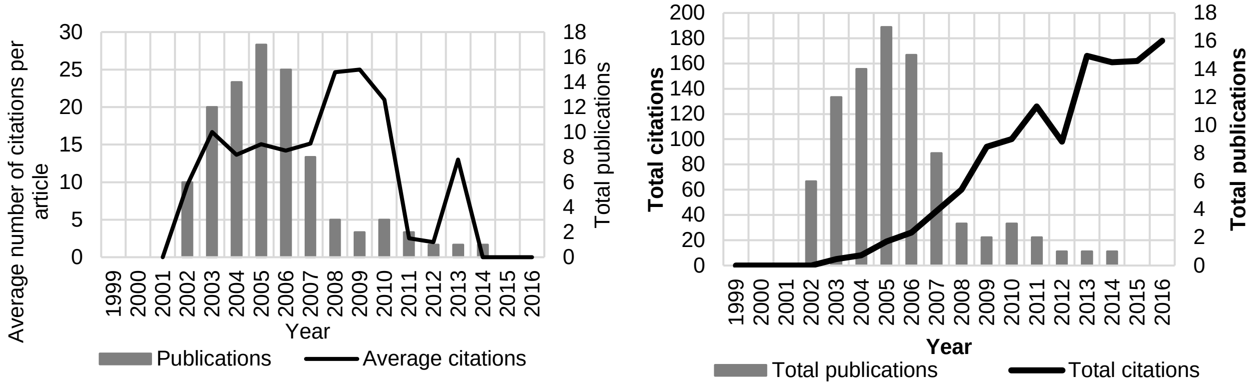


Figure 11.5: Citation trends of WARFSA-funded research articles

Source: Clarivate Analytics™ Web of Science™

The citation distribution of WARFSA-funded articles is presented in Table 11.4, where the number of articles and the number of citations are presented in citation ranges of 10. Here it is evident that four articles (less than 5%) had never been cited, with the majority of articles, almost half of all articles, being cited between 1 and 10 times, and reflecting 21% of all citations.

Table 11.4: Distribution of articles and citations from WARFSA-funded research

Citation range	**Number of articles**	**% of articles**	**Number of citations**	**% of citations**	**Average number of citations**
0	4	4,71%	0	0,00%	0
1–10	42	49,41%	260	20,87%	6,19
10–20	21	24,71%	305	24,48%	14,52
20–30	3	3,53%	72	5,78%	24,00
31–40	10	11,76%	352	28,25%	35,20
41–50	2	2,35%	87	6,98%	43,50
51–60	3	3,53%	170	13,64%	56,67
61–70	0	0,00%	0	0,00%	0
71–80	0	0,00%	0	0,00%	0
81–90	0	0,00%	0	0,00%	0
91–100	0	0,00%	0	0,00%	0
100+	0	0,00%	0	0,00%	0
500+	0	0,00%	0	0,00%	0
Totals	**85**	**100%**	**1 246**	**100%**	
Average citation rate			**0,92**		
SADC-ExSA average citation rate*			0,51		
South Africa average citation rate*			0,49		
SADC average citation rate*			0,50		

* Refer to Table 11.3

Source: Clarivate Analytics™ Web of Science™

There are quite a number of articles cited between 31 and 40 times, which reflects 28% of all citations. There are also no articles that had more than 60 citations. It is evident that 46% of articles accounted for 79% of all citations. Following Lotka's observations (1926), it is not uncommon that only a few articles often account for the most citations.

If one were to consider the citation rate for the different citation ranges, it becomes evident that for almost half of the WARFSA articles, the average article has been cited, just over six times. In addition, 25% of the articles have been cited, on average, just over 14 times. On the other end of the scale, it is evident that a small percentage of articles, just over 3%, had an average citation rate of 56,6 citations per article.

The annual distribution of the citations per citation range is presented in Figure 11.6 where it is evident that most articles, which had never been cited, along with the articles which received fewer than 10 citations, were published in the early part of the WARFSA programme, between 2002 and 2005. In addition, articles receiving more citations were published in the middle of the programme and later around the 2007/2008 when the WARFSA programme concluded. For example, there were three articles with citations between 51 and 60, which were published in 2003 and 2004, and a few with citations between 40 and 50 that were published in 2005 and 2008. One should keep in mind, that by this time, the annual WaterNet/WARFSA/GWP SA symposium and the WaterNet master's degree programme were well under way, by then in its fifth, sixth and seventh year, providing a consistent platform to disseminate research. Moreover, as evident from previous chapters, significant increases were observed in water research output during this time, especially in SADC-Ex-SA countries. Given the close alignment of the WARFSA programme with the annual symposium, along with the increased water research in the SADC region, it would suggest that research in the region was growing, with more water researchers in the sector continuing relevant research that was increasingly cited.

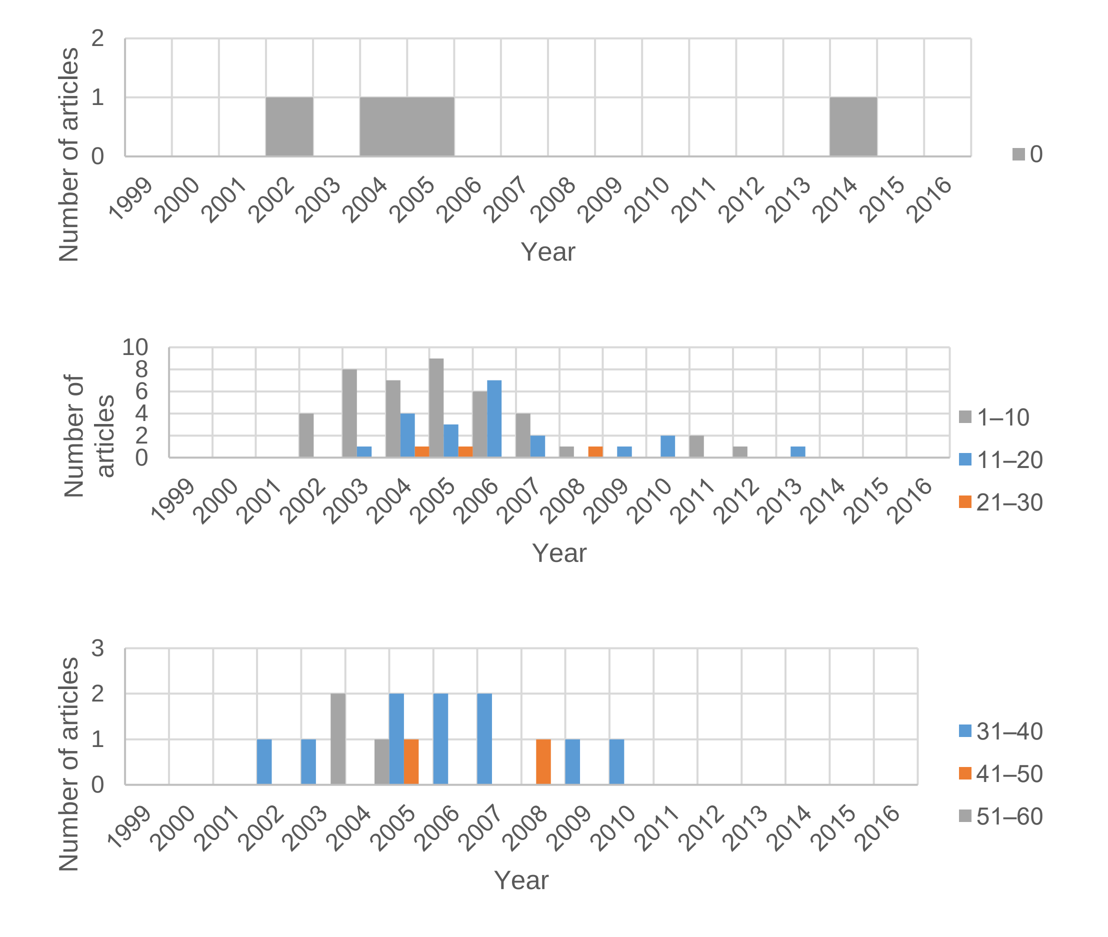


Figure 11.6: Annual distribution of WARFSA-funded research articles in citation ranges of ten

Source: Clarivate Analytics™ Web of Science™

Our focus now shifts to the citation impact, of WARFSA articles. . We have already noticed that the citation rate of these articles was above average, when compared with other water research in the SADC region, and that a significant increase occurred in the citation rate during 2008, 2009 and 2013.

11.3.2.1 Citation impact

The citation rate provides an indication of citation trends, but it is further important that citation data be normalised, to consider factors such as the degree to which references from other fields are cited, differences amongst fields in the average number of cited references per publication, the way the number of citation always increase over time and the average age of cited references. The mean normalised citation score (MNCS) (Leydesdorff et al., 2011; Waltman et al., 2011) provide such an indicator. For a more detailed discussion on the MNCS, refer to section 5.3.2.1). In addition, citation scores are normalised by the number of years since articles were published.

Through the analysis of citation data of articles published as part of the WARFSA programme, the average annual citation scores are presented in Table 11.5, with the distribution of the average annual citation rate presented in Figure 11.7. Considering that the first phases of the WARFSA programme started in 1999 and concluded in 2007, it is evident that publications increased gradually (Figure 11.7), along with an increase in the average annual citation rate. The highest number of articles were published in 2005, after which the annual number of articles gradually decreasing, along with the conclusion of the WARFSA programme. Citations of articles however increase, with the few articles published in 2008, 2009, 2010 and 2013, being cited most.

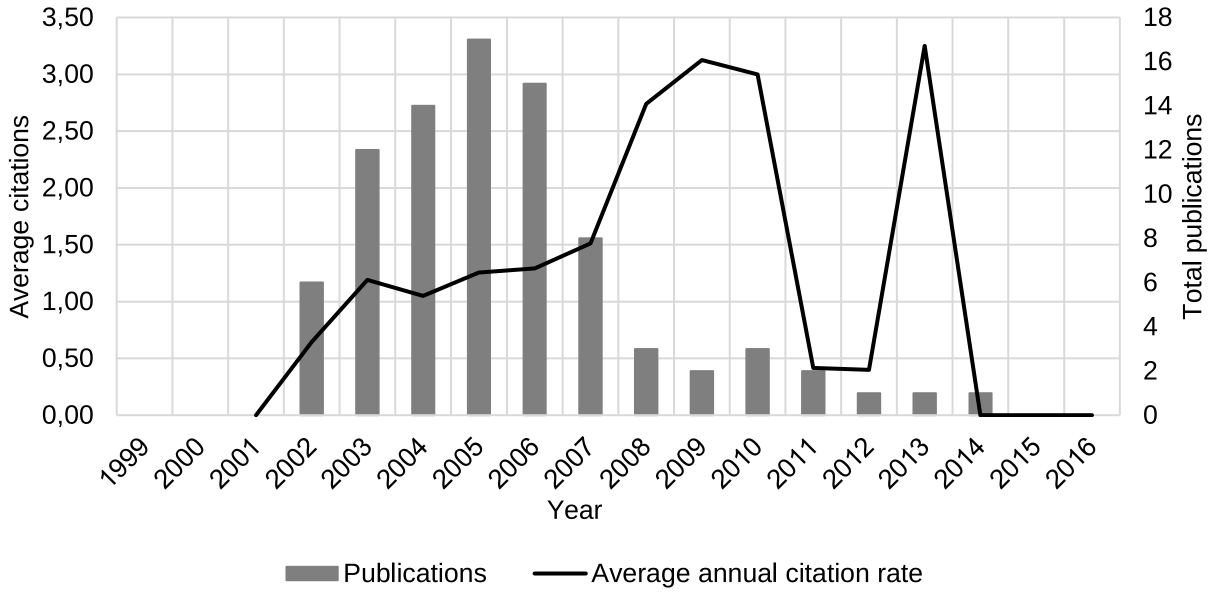


Figure 11.7: Average annual citation rate publications from the WARFSA (2001–2016)

Source: Clarivate Analytics™ Web of Science™

The MNCS values for WARFSA articles were calculated and are presented in Table 11.6 with the annual distribution of the MNCS presented in Figure 11.8: Distribution of the MNCS of WARFSA, SADC-ExSA and South African water research (1980–2016). As reference, the MNCS-values of water research from South Africa and SADC-ExSA countries, which were calculated in the previous chapters 9 (section 9.3.1) and chapter 10 (section 10.3.1) respectively, are presented in Figure 8.16. A MNCS-value of 1 means that the citation impact of a specific set of publications are generating citation rates equal to the world average for publications in that field. From the citation data analysis, the MNCS-values for WARFSA articles have, in general, been below 1, thus below the world average for publications in the same research fields. There were however specific years, such as 2008, 2009 and 2013, where WARFSA articles were being cited well above the world average. When compared to South African and SADC-ExSA water research, it is evident that WARFSA articles are, in general, less visible, except for the articles published in 2008, 2009 and 2013.

Table 11.5: Citations of WARFSA articles (2001–2016)

		Citations per year																		
Year	**Total arti-cles (A)**	**01**	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**Total number of citations (B)**	**Average number of citation C=(B/A)**	**Average annual citation rate (D=C/number of years)**
2001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,00
2002	6		0	5	3	2	3	5	6	4	4	5	2	5	4	5	5	58	9,67	0,64
2003	12			0	5	12	4	15	11	20	17	23	18	28	11	20	16	200	16,67	1,19
2004	14				0	5	15	9	8	16	19	14	13	22	25	23	22	191	13,64	1,05
2005	17					0	4	10	12	21	24	26	15	44	21	36	43	256	15,06	1,25
2006	15						0	4	18	18	11	25	20	25	38	23	31	213	14,20	1,29
2007	8							0	5	7	9	14	14	16	15	19	22	121	15,13	1,51
2008	3								0	7	11	10	6	11	10	7	12	74	24,67	2,74
2009	2									1	5	7	5	5	13	6	8	50	25,00	3,13
2010	3										0	2	4	10	18	17	12	63	21,00	3,00
2011	2											0	1	0	2	1	1	5	2,50	0,42
2012	1												0	0	1	1	0	2	2,00	0,40
2013	1													0	3	4	6	13	13,00	3,25
2014	1														0	0	0	0	0,00	0,00
2015	0															0	0	0	0,00	0,00
2016	0																0	0	0,00	0,00
TOTAL	**85**	**0**	**0**	**5**	**8**	**19**	**26**	**43**	**60**	**94**	**100**	**126**	**98**	**166**	**161**	**162**	**178**	**1 246**		

Source: Clarivate Analytics™ Web of Science™

Table 11.6: Mean normalised citation scores (MNCS) of SADC-ExSA

Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Number of publications	5	11	13	16	15	8	3	2	3	2	1	1	1
MNCS	0,5121	0,4627	0,4171	0,2275	0,3866	0,3841	1,4091	1,5706	0,4274	0,1026	0,2447	1,3778	0,0000

Note: The number of publications in Figure 11.7 are fewer than the number of publications in Figure 11.6, as the calculation of the MNCS only consider the number of articles, letters and reviews, whereas Figure 11.6, present all document types.

Source: Clarivate Analytics™ Web of Science™ and calculated by the CREST

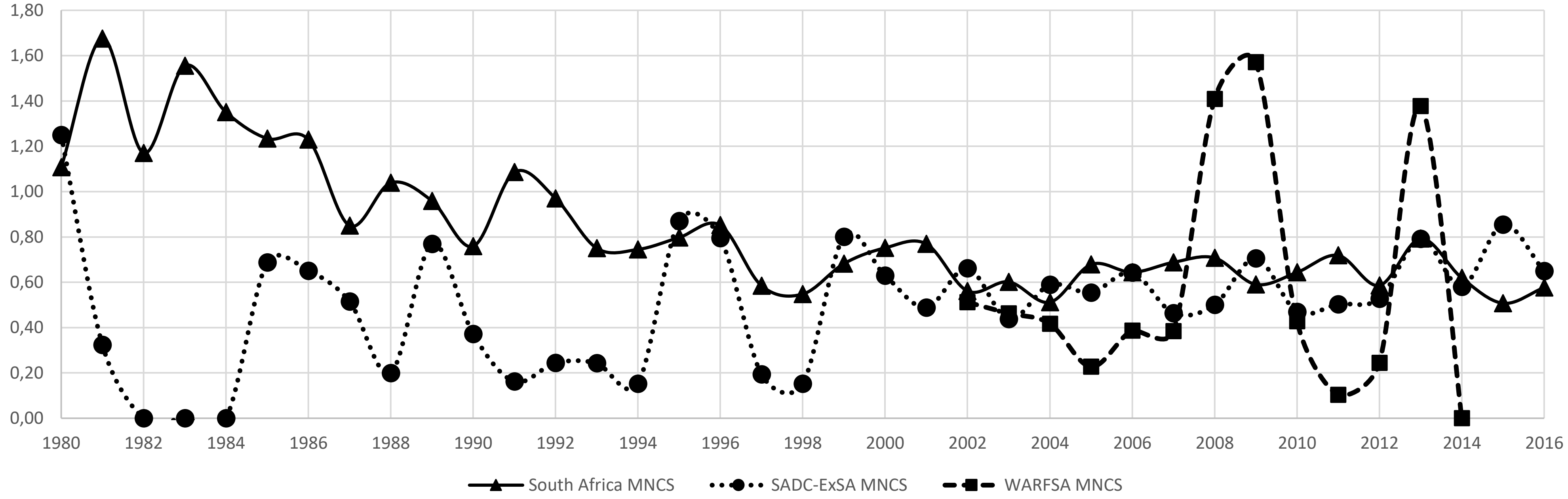


Figure 11.8: Distribution of the MNCS of WARFSA, SADC-ExSA and South African water research (1980–2016)

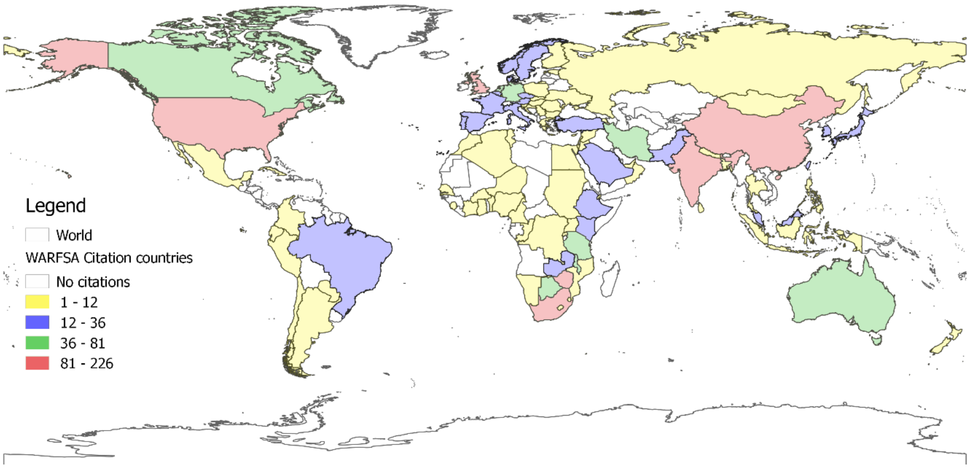
Source: Clarivate Analytics™ Web of Science™

To conclude, it is evident that almost all articles from the WARFSA programme have been cited, with many articles published later in the implementation period of the programme being cited more often than others. As can be expected, the number of articles published declined after the WARFSA programme concluded in 2007, whoever, there were articles published in 2008, 2009, 2010 and 2013 which not only received a high number of citations, but were well above the global average for articles in the same field. In general, WARFSA articles are less visible than the South African, other SADC-ExSA and global water research, even though the average annual citation rate of WARFSA articles are higher.

In the previous sections, various aspects relating to the citing of WARFSA-funded research have been discussed, namely the citation scores, annual average citation rate and the global visibility of WARFSA articles. The question can now be asked who the researchers are that cite WARFSA-funded research, and from which countries or regions they originate. The next section will address this question.

11.3.3 Global citation footprint of WARFSA-related articles

Research articles from WARFSA-funded projects were cited by researchers from various countries around the world, and the results of the bibliometric data analysis are presented in Figure 11.9. Here it is evident that 32% of the articles were cited by researchers on the African continent, followed by 31% from Europe, 25% from Asia, 8,8% from North America, 2,6% from South America and less than 1% from Australasia.



Africa	660	32,4%
Europe	637	31,2%
Asia	505	24,8%
North America	180	8,8%
South America	53	2,6%

Figure 11.9: Map: Continental and sub-regional distribution of countries citing WARFSA-funded research articles

Source: Clarivate Analytics™ Web of Science™

Table 11.7 lists the top 20 countries from where researchers who have cited WARFSA-funded articles originated. For each of the countries, Table 11.7 presents the number of times a researcher from a specific country cited WARFSA-funded articles. It is evident that research articles from the WARFSA programme were cited by various researchers in 106 countries, with researchers from South Africa (11,1%) being the most, followed by the researchers from the People's Republic of China (7,1%), the United States (6,1%), Zimbabwe (5,2%) and India (4,5%). The rest of the top 20 countries are United Kingdom (England), the Netherlands, Germany, Australia, Botswana, Tanzania, Iran, Canada, Malawi, Brazil, Malaysia, Japan, Turkey, France and Switzerland. In addition, the top 20 countries comprised 69% of the country affiliations of researchers who have cited WARFSA-funded articles.

Table 11.7: Country affiliations of researchers citing WARFSA-funded research (top 20 countries)

Rank	Country	Total	%
1	South Africa	226	11,1%
2	PRC	144	7,1%
3	USA	124	6,1%
4	Zimbabwe	107	5,2%

	Rank	Country	Total	%
	5	India	91	4,5%
	6	UK (England)	88	4,3%
	7	Netherlands	81	4,0%
	8	Germany	61	3,0%
	9	Australia	59	2,9%
	10	Botswana	54	2,6%
	11	Tanzania	51	2,5%
	12	Iran	46	2,3%
	13	Canada	43	2,1%
	14	Malawi	43	2,1%
	15	Brazil	36	1,8%
	16	Malaysia	35	1,7%
	17	Japan	31	1,5%
	18	Turkey	30	1,5%
	19	France	29	1,4%
	20	Switzerland	28	1,4%
Other countries	86		632	31,0%
Total	**106**		**2 039**	**100%**

Source: Calculated from data sourced from Clarivate Analytics™ Web of Science™

The African country affiliations of researchers citing WARFSA-funded articles are presented in Table 11.8, where it is evident that the research was cited by researchers from 32 African countries. As indicated earlier, researchers from South Africa, Zimbabwe, Botswana, Tanzania and Malawi were the most frequent authors. Incidentally, these were the SADC-ExSA countries that had experienced the most significant increase in water research over the previous two decades, as determined in the previous chapters (see 7.2.1 and 10.2.2.3). This suggests an active science community finding research from the WARFSA programme of value to them.

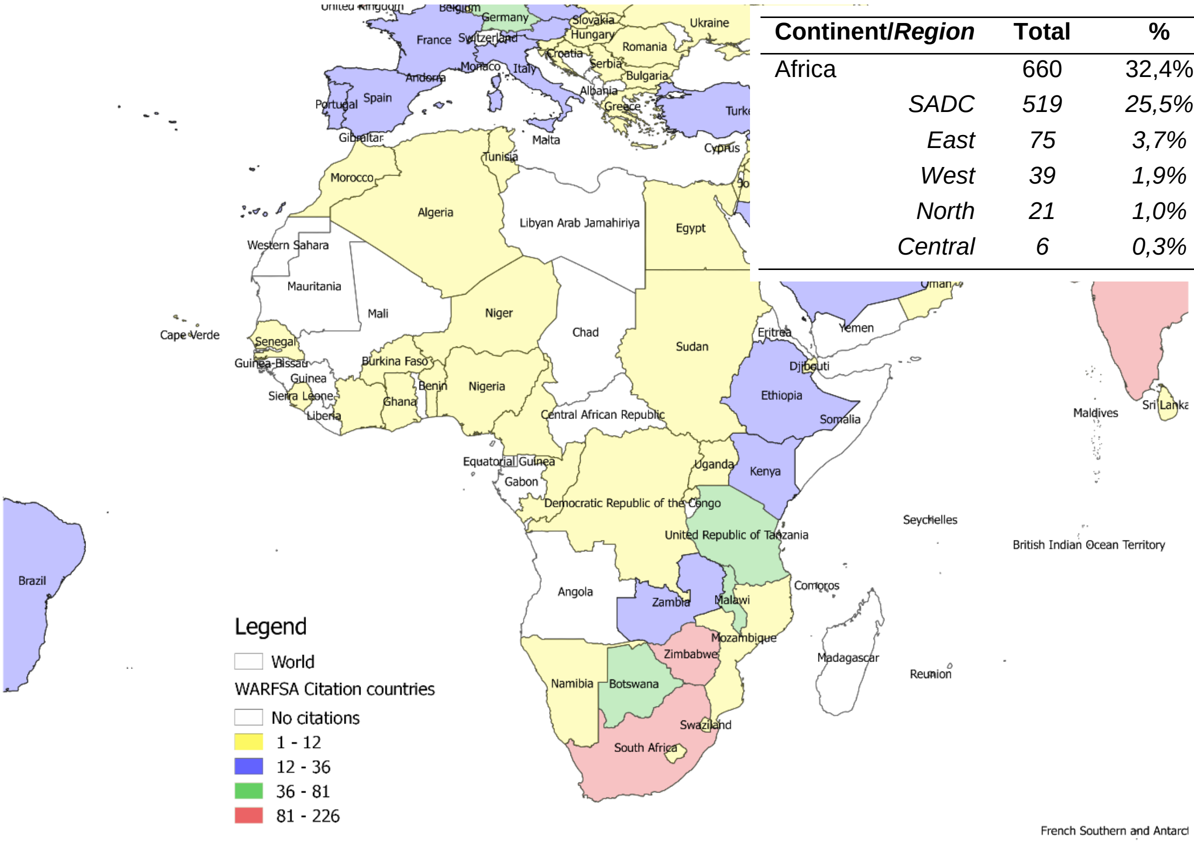
Table 11.8: African country affiliations of researchers citing WARFSA-funded research

Number	African country	Count	%	African region
1	South Africa	226	11,1%	SADC
2	Zimbabwe	107	5,2%	SADC
3	Botswana	54	2,6%	SADC
4	Tanzania	51	2,5%	SADC
5	Malawi	43	2,1%	SADC
6	Ethiopia	25	1,2%	East
7	Kenya	20	1,0%	East
8	Zambia	14	0,7%	SADC
9	Egypt	12	0,6%	East
10	Swaziland	12	0,6%	SADC
11	Nigeria	12	0,6%	West
12	Ghana	10	0,5%	West
13	Tunisia	8	0,4%	North
14	Rwanda	7	0,3%	East
15	Uganda	7	0,3%	East

Number	African country	Count	%	African region
16	Morocco	7	0,3%	North
17	Algeria	6	0,3%	North
18	Namibia	6	0,3%	SADC
19	Burkina Faso	5	0,2%	West
20	Côte D'Ivoire	4	0,2%	West
21	Cameroon	3	0,1%	Central
22	Congo	3	0,1%	Central
23	Sudan	3	0,1%	East
24	Mozambique	3	0,1%	SADC
25	Benin	3	0,1%	West
26	DRC	2	0,1%	SADC
27	Niger	2	0,1%	West
28	Djibouti	1	0,0%	East
29	Lesotho	1	0,0%	SADC
30	Cape Verde	1	0,0%	West
31	Senegal	1	0,0%	West
32	Sierra Leone	1	0,0%	West
	Total	**660**		

Source: Calculated from data sourced from Clarivate Analytics™ Web of Science™

Table 11.8 and Figure 11.10 present the distribution of African countries citing WARFSA-funded articles, where it is evident that researchers from the SADC region have cited the articles most (25%), followed by researchers from East African countries (3,7%), West Africa (1,9%), North Africa (1%) and Central Africa (less than 1%). African countries that have cited WARFSA-funded articles more than 10 times, are South Africa (226 times), Zimbabwe (107 times), Botswana (54 times), Tanzania (51 times), Malawi (43 times), Ethiopia (25 times), Kenya (20 times), Zambia (14 times), Egypt (12 times), Swaziland (12 times), Nigeria (12 times) and Ghana (10 times). It is clear that many of these countries are in Southern and East Africa.



Continent/*Region*	Total	%
Africa	660	32,4%
SADC	*519*	*25,5%*
East	*75*	*3,7%*
West	*39*	*1,9%*
North	*21*	*1,0%*
Central	*6*	*0,3%*

Figure 11.10: Map: Distribution of African countries citing WARFSA-funded articles

Source: Clarivate Analytics™ Web of Science™

The many site and topic-specific research projects in the WARFSA programme could explain the relevance of the research to other researchers in the SADC sub-region. Increased co-publishing trends, not only in the SADC region but further with other African and beyond Africa, could also contribute towards research being useful to other researchers globally, as established earlier in this section.

Having considered the publication and citation aspects of the WARFSA-funded articles, our attention can now shift towards the final section in this chapter, where the institutional associations of the researchers are considered.

11.3.4 Institutional associations of publishing researchers

Water research in the WARFSA programme was primarily funded through the WARFSA fund, with researchers from institutions in the SADC region being able to apply for funding. Applications were on a competitive basis, and were evaluated by the scientific committee and approved by the WARFSA board. The bibliometric analysis of the 85 articles indicate that researchers affiliated with the University of Zimbabwe produced the most research articles (23,5%), followed by the University of Dar es Salaam in Tanzania, producing 13% of articles (Table 11.9). This is not surprising, as 46% of research projects were awarded to researchers from Zimbabwe, followed by Tanzania (18%), South Africa (10%), Swaziland and Zambia 7% respectively. WARFSA progress reports indicate that this is closely linked to the number of applications, where institutions from these institutions submitted the largest number of applications (WARFSA, 2005). Moreover, a WARFSA report (2005) indicates that not all applications for WARFSA funding were approved. On average, between 23% and 33% of the applications per country were funded. For example, 27% of applications in Zimbabwe, 25% of applications in Tanzania and Malawi, 23% of applications from Zambia, and 56% of applications from Swaziland were funded.

As evident from Table 11.9, other institutions publishing more than three articles from WARFSA funding, are UWC (South Africa), UNIMA (Malawi), UJ (South Africa), UNISWA (Swaziland), the University Lake Kariba Research Station (Zimbabwe). In addition, the Leeds Metropolitan University[43] (United Kingdom), the Centre for Research Environment and Health at the University of Zambia (Zambia), Wits (South Africa), the UB (Botswana), the SUA (Tanzania), the CSIR (South Africa), the Copperbelt University (Zambia), UP (South Africa) and IWSD (Zimbabwe) further published more than three articles each in the WARFSA programme. Where research institutions from outside SADC are indicated, such as the Leeds University, this indicates research collaboration in projects.

Table 11.9: WARFSA Research article publications per institutions

Research institutions	Country	Records	% of 85
University of Zimbabwe (UZ)	Zimbabwe	20	23,53%
University of Dar es Salaam (UDSM)	Tanzania	11	12,94%
University of Cape Town (UCT)	South Africa	7	8,24%
University of Malawi (UNIMA)	Malawi	6	7,06%
University of Johannesburg (UJ)	South Africa	6	7,06%

[43] Note that Leeds Metropolitan University changed its name in 2014 to Leeds Beckett University (Leeds Beckett University, 2014)

Research institutions	Country	Records	% of 85
University Swaziland (UNISWA)	Swaziland	6	7,06%
University Lake Kariba Research Station	Zimbabwe	6	7,06%
Leeds Metropolitan University (LMU)	United Kingdom	5	5,88%
Centre for Research Environment and Health	Unknown	5	5,88%
University of Zambia (UNZA)	Zambia	4	4,71%
University of the Witwatersrand (Wits)	South Africa	4	4,71%
University of Botswana (UB)	Botswana	4	4,71%
Sokoine University of Agriculture (SUA)	Tanzania	4	4,71%
Council for Scientific Industrial Research South Africa (CSIR)	South Africa	4	4,71%
Copperbelt University	Zambia	4	4,71%
University of Pretoria (UP)	South Africa	3	3,53%
Institute for Water and Sanitation Development (IWSD)	Zimbabwe	3	3,53%

Note: Minimum number of research articles per institution = 3

Source: Clarivate Analytics™ Web of Science™

It is thus evident that researchers from mostly SADC countries published articles from the WARFSA programme, with researchers from Zimbabwe and Tanzania alone publishing more than 35% of the articles, thus contributing towards the research capacity in these countries. As indicated, this is closely linked to the number of applications from these countries, and further linked to the number of awards granted. There are further researchers from beyond the SADC region contributing to the publishing of articles, thus strengthening their capacity, knowledge and co-operation with researchers from the region.

11.4 Results summary and conclusion

Researchers are confronted with providing evidence of the ‘impact of research’. Moreover, the assessment of the impact or influence of research is difficult enough at the best of times, with challenges associated with the attribution or contribution of influences to specific research projects common. This is highlighted when a programme such as Phases I and II of the WARFSA were undertaken 10 to 15 years after the programme had been concluded, with many researchers simply not available to assess such influences. Taking a first step, and making use of scientometric techniques such as the bibliometric analysis of publication and citation data, the scientific influence of articles were analysed and especially where the time lag has been an advantage, as evident in this thesis.

This chapter aimed to analyse the scientific influence the WARFSA programme had on water research in the SADC region, by assessing the knowledge, innovations and products produced. The results are summarised below:

From a bibliometric perspective, the analysis of knowledge produced from research funded by the WARFSA programme, was a project of two parts. On the one hand, research outputs were identified and assisted in identifying the extent of research outputs which emanated from the WARFSA-funded research projects. On the other hand, a few research outputs were published in peer-reviewed journals, from where citation data could be extracted. The discussion will therefore initially present the analysis of all research output, which is followed by the bibliometric analysis of the articles published in peer-reviewed journals as captured in the Clarivate Analytics™ Web of Science™.

→ **Results of all research output**

Based on available information, at least 230 research outputs were produced from the WARFSA programme, with articles in scientific journals (44%) and conference proceedings (43%) the most common. In addition, 75 (33%) post-graduate degrees in the form of PhDs and master's degrees were identified from research projects associated with the WARFSA programme. A few technical reports (6%), book chapters (3%) and policy documents (2%) were further identified.

1 The bulk of research outputs were produced between 2000 and 2006. During this time, 69% of the 230 research outputs were produced.

2 Almost 30% of all research outputs were published in the scientific journal *Physics and Chemistry of the Earth*. In terms of the number of authors per publication, 47,4% of the research outputs where contributed by a single author, followed by contributions with three authors (20,4%), two authors (13,5%) and four authors at 9,6%. In addition, 21 research outputs, comprising 9,1%, were published with five and more authors. It is further evident that most of the single-authored research outputs were produced in the early years of the WARFSA programme in 2002. For the duration of the implementation period of the WARFSA programme, multiple-authored research outputs increased, with the most reaching a peak towards the end of the WARFSA implementation period in 2006/2007. As can be expected, research outputs declined following 2007, when support for the WARFSA programme formally concluded.

→ **Results of the bibliometric study of articles available in WoS citation database**

3 The study further found that 85 articles were published in peer-reviewed journals with publication and citation data available in the WoS. These articles formed the basis for further bibliometric analysis.

4 Of these articles, 80% were published in the journal *Physics and Chemistry of the Earth*. The balance of the articles were published in journals namely *Water SA, Onderstepoort Journal of Veterinary Research, Aquatic Ecology, Plant Ecology, Transactions of The Royal Society of Tropical Medicine and Hygiene, Journal of Arid Environments, Applied Geochemistry, African Journal of Ecology, Hydrogeology Journal, Bulletin of Environmental Contamination and Toxicology*, the *Japanese Journal of Veterinary Research, Environmental Monitoring and Assessment,* and *Water International*.

5 Articles have been cited 1 246 times,[44] with a steady build-up of citations since 2005, to 178 citations in 2016, at a citation rate 0,92 per article. When this rate is compared to the citation rate of water research in the SADC region and from elsewhere on the African continent, it is significantly higher than the citation rate for articles published during the same period in the SADC region. This would suggest that water research emanating from WARFSA projects was of more interest to the scientific community, and therefore it was cited more often.

6 Less than 5% of articles were never cited, with the majority of articles, almost half of all articles, cited just over six times, and receiving 21% of all citations. These articles were published in the early part of the WARFSA programme, between 2002 and 2005.

7 There are further quite a number of articles (12%) cited between 31 and 40 times. These articles received 28% of all citations, with 46% of articles accounting for 79% of all citations. These articles were published later and just after the WARFSA programme ended around 2007/2008. One should keep in mind that, by this time, the annual WaterNet/WARFSA/GWP SA symposium and WaterNet master's degree programme were well under way, by then in its fifth, sixth and seventh year. Moreover, as was evident in previous chapters, significant increases were observed in water research output during this time, especially in SADC-Ex-SA countries. Given the close association of the WARFSA programme with the annual symposium, along with the increased water research in the SADC region, this would suggest that research in the region was growing, with more water researchers in the sector continuing relevant research that was increasingly cited.

8 If one were to further to consider the distribution of citations of WARFSA-funded articles, it is evident that articles published in 2008 and 2009 (after the conclusion of the WARFSA programme), were on average, cited more than articles published between 2002 and 2007, and more recently in 2013.

9 It is evident that almost all articles from the WARFSA programme have been cited, with many articles published later in the implementation period of the programme being cited more often than others. As can be expected, the number of articles published declined after

[44] Include self-citations.

the WARFSA programme concluded in 2007, whoever, there were articles published in 2008, 2009, 2010 and 2013 which not only received a high number of citations, but were well above the global average for articles in the same field. In general, WARFSA articles are less visible than the South African, other SADC-ExSA and global water research.

10 Research articles from WARFSA-funded projects, were cited by researchers from 106 countries around the world, with 32% of the articles cited by researchers on the African continent, followed by 31% from Europe, 25% from Asia, 8,8% from North America, 2,6% from South America and less than 1% from Australasia. The top countries were South Africa (11,1%), followed by the People's Republic of China (7,1%), the United States (6,1%), Zimbabwe (5,2%) and India (4,5%), with the top 20 countries accounting for 69% of all citations.

- In terms of African countries, WARFSA-related articles were cited most by researchers from the SADC region (25%), followed by researchers from East African countries (3,7%), West Africa (1,9%), North Africa (1% and Central Africa less than 1%).
- African countries that have cited WARFSA-funded articles more than ten times were South Africa (226 times), Zimbabwe (107 times), Botswana (54 times), Tanzania (51 times), Malawi (43 times), followed by Ethiopia, Kenya, Zambia, Egypt, Swaziland, Nigeria and Ghana with many of these countries in Southern and East Africa. It is evident that WARFSA-funded research is cited by various African researchers. This can be attributed to increased collaborations with water researchers from other African counties, as is evident in the increased co-authorship of articles trends with SADC countries.

  The many site and topic-specific research projects in the WARFSA programme could explain the relevance of the research to other researchers in the SADC sub-region. Increased co-publishing trends, not only in the SADC region but further afield with other African and global researchers, could also contribute towards research being useful to other researchers globally, as established in earlier chapters of this study.

11 In terms of the institutional associations, researchers from Zimbabwe and Tanzania alone publishing more than 35% of the articles. As indicated, this is closely linked to the number of WARFSA funding applications from these countries, and further linked to the number of awards distributed during the WARFSA programme. There are further researchers from beyond the SADC region contributing to the publishing of articles, thus strengthening their capacity, knowledge and co-operation with researchers from the region.

In conclusion, it is clear that the WARFSA programme contributed significantly towards the scientific knowledge in the SADC water sector during its implementation between 2000 and 2006, and specifically in research institutions in the SADC-ExSA countries, with quite a few post-graduate degrees resulting from the programme. Research articles published were (and still are to this day), being cited by the research community, not only regionally, but further afield beyond Africa and globally, indicating their relevance, even after the conclusion of the programme approximately 10 years ago. One do however have to acknowledge that even though these articles are widely cited, their visibility are well below the South African, other SADC countries and global average.

Chapter 12

POLICY AND PRACTITIONER ASPECTS EVIDENT FROM WARFSA-FUNDED RESEARCH PROJECTS

12.1 Introduction

In the previous chapters of this thesis, the focus was very much on the knowledge production of water research in the SADC region, with various universities and research institutions contributing towards the research output. In addition, the Water Research Fund for Southern Africa (WARFSA) was conceived in the late 1990s, with the specific aim to build research capacity development (Van der Zaag, 2005; Wright et al., 2001). Even though the initial implementation period for the WARFSA was limited to the early to mid-2000s, the idea around the special fund was continuously supported by the ministers of water in the region, as evident in the various SADC Regional Strategic Action Plans on Integrated Water Resource Management and Development (commonly referred to as the RSAPs). In this thesis so far, the heavy reliance of countries in the SADC region on external donor support for water research has been highlighted, especially in SADC countries excluding South Africa. This has contributed towards the WARFSA not being implemented for many years, given its SADC regional focus. One could argue that, as there are so many countries in the SADC region, mobilising 'local' resources for such a fund would be an option, but the reality has been that so far, this has not been possible. There are however renewed plans to revive the WARFSA (see NEPAD SANWATCE, 2016), with this study thus providing opportune perspectives on previous knowledge production in the SADC water sector, research output emanating from the WARFSA during previous implementations, and policy and practitioner experiences relating to the implementation of the WARFSA, as presented in this chapter.

It is increasingly required from universities and research institutions to report on the outcome of their research, not only as it translates into policy and practice, but also further in terms of how the research affects society. Often, such pressure comes from policymakers and decision-makers who need to formulate policies for the wellbeing of society at large. Research in research utilisation and knowledge production is well documented by notable authors such as Evertt Rogers (2003), Jonathan Caplan (1977; 1979), Ronald Havelock (1969), Jack Knott and Aaron Wildavsky (1980), Robert Rich (1977; 1979; 1991), Carol Weiss (1977a; 1979; 1980; 1977b). In the 1990s and more recently, authors such as Michael Gibbons, Helga Nowotny, Camille Limognes and Peter Scott (1994; 2001; 2003), Henry Etzkowitz and Loet Leydesdorff (1998), Hank Jenkins-Smith (1990) and Sabatier and Jenkins-Smith (1993) contributed towards the study field of research utilisation and knowledge production with Paul Sabatier also collaborating with Weible (2007).

Various research utilisation theories, models and frameworks resulted from these studies, such as the –

- knowledge-driven model (Weiss, 1979:427);
- problem-solving model (Weiss, 1979:427);
- interactive model (Weiss, 1979:428);
- political model (Weiss, 1979:429);
- tactical model (see Weiss, 1979:429);
- enlightenment model (Weiss, 1979:429);
- Havelock's linkage model (1969);
- advocacy coalition framework (Jenkins-Smith, 1990; Jenkins-Smith & Sabatier, 1994; Sabatier & Jenkins-Smith, 1993); and
- Caplan's two-communities theory (1979).

Often, these frameworks influenced other researchers such as Lindquist (1990; 2001) presenting the existence of a 'third community' inside and outside government but being able to influence high-level decision-making, and Klein (1990) introducing *interdisciplinarity* and Gibbons et al. (1994) introducing Mode-2 knowledge production, giving greater prominence to the broader co-production and uptake of knowledge, which involved a wide range of role players from the research community, policymakers, industry and society.

These models and frameworks also influenced the development of research impact frameworks, such as –

- the HERG Payback Framework (see Buxton & Hanney, 1996);
- the Research Impact Framework (see Raftery et al., 2016);
- the Canadian Academy of Health Sciences (CAHS) framework (see Canadian Academy of Sciences, 2009);
- Societal Impact Assessment and Related Approaches (see Spaapen & Sylvain, 1994);
- the UK Research Excellence Framework (REF) (see HEFCE, 2015); and
- the Participatory Research Impact Model (see Cacari-Stone et al., 2014).

Studies such as those by Boaz et al. (2009) and Greenhalgh et al. (2016) concluded that the HERG Payback Framework was used most widely among researchers to evaluate the influence of research.

As one of its elements, the HERG Payback Framework (Buxton & Hanney, 1996), as presented in Chapter 2 of this study, provides four research impact dimensions, namely knowledge production, policy impact, economic benefits and social benefits as derived from research (with this study focussing on knowledge production and policy uptake). If one were to consider the first research impact dimension, knowledge production, Chapter 11 introduced an analysis of research outputs from the WARFSA programme, and presented publication and citation aspects related to the programme. Even though the implementation period of Phases I and II of the programme ran between 1999 and 2007, the analysis covers the period between 1999 and 2016. Chapter 12 further reports on the second research impact dimension and policy impact, again considering the 78 research projects in Phases I and II of the WARFSA-programme. Given the limited meta-data that are available on the WARFSA programme, as discussed earlier in this study (see 5.4.1), it is important to note that the objective of this chapter is not to conclude quantitatively how many projects translated into some form of policy or practitioner uptake, but rather to report on a qualitative analysis of themes which contributed (or not contributed) to the translation of research into policy or practitioner uptake. Moreover, to relate this chapter to the policy and practitioner aspects of the HERG Payback Framework, Figure 12.1 is presented. Here it is evident that policymaking and the adoption of research by practitioners and the public, as presented in this chapter, stem from the dissemination activities after the research outputs had been produced. In this study, research outputs from the WARFSA were presented in Chapter 11. In addition, policymaking and the adoption by practitioners are further influenced by the stock of knowledge, along with influences from the political, professional and industrial environment, and wider society. This is in line with ideas related to Mode 2 knowledge production, arguing in favour of knowledge production that is more "socially distributed, application-orientated, trans-disciplinary and subject to multiple accountabilities" (Nowotny et al., 2003:179) and part of larger innovation processes and innovation ecosystems.

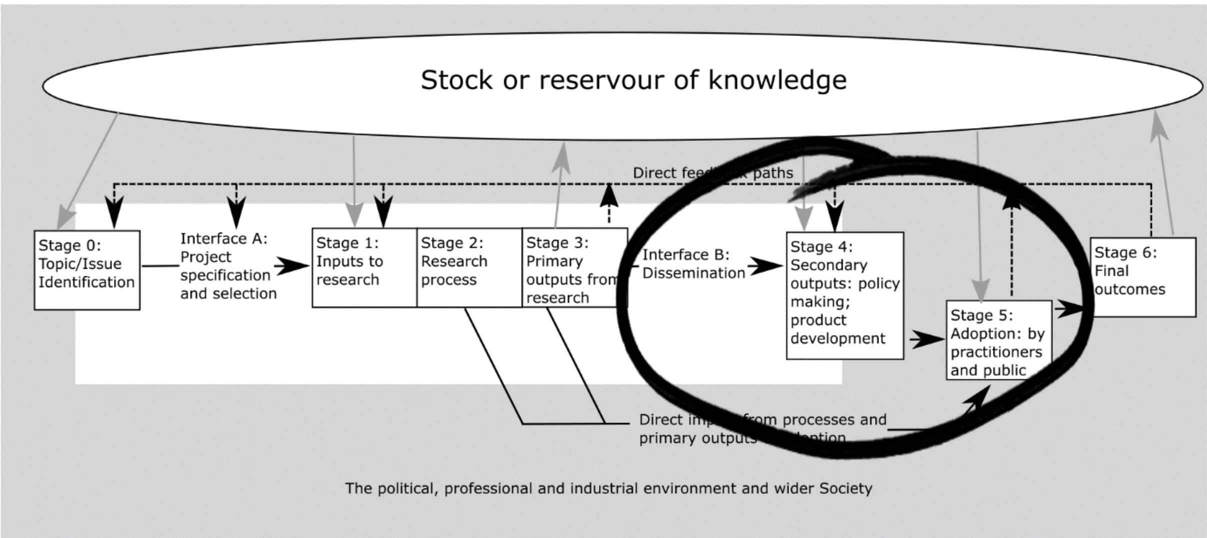


Figure 12.1: The policy- and practitioner aspects in the HERG Payback Framework

Source: Adapted from Hanney et al. (2004)

12.2 Research methodology

For detail on the methodology used to collect qualitative data for this section of the study, refer to the research methodology chapter, and specifically section 5.4.1.

The following two sections first present the context of the SADC water sector in the early 2000s, followed by the background of the research projects as case studies. This is followed by a cross-case analysis and discussion of themes, which resulted from the interviews. Where coded sections are presented as quotes, the name of the interviewee, the document number and coded section number are presented in brackets. Please note that all quotations are reproduced verbatim and unedited.

12.3 Case studies – Background to the projects

The regional context, reflecting on the policy environment of the SADC water sector in the early 2000s, is an important factor when considering the policy dimension of the WARFSA-funded research, as it provides the context within which Phases I and II of the WARFSA were implemented. Foremost was a heightened focus on integrated water resource management (IWRM), as evident through the implementation of the first Regional Strategic Action Plan on Integrated Water Resource Management and Development (known as the RSAP I) (see SADC, 1999). This first strategy was implemented from 1999 to 2004, and developed and implemented through the SADC Water Desk in Gaborone. Subsequently, the RSAP has been updated in five-year cycles, with the RSAP II (2005 to 2010) (see SADC, 2005), RSAP III (2011 to 2015) (see SADC, 2011) and the latest update, RSAP IV for the period 2016 to 2021 (see SADC, 2016).

During the interviews, some respondents highlighted an optimism in some countries, which also filtered through to the regional SADC water sector where, for example, Dr Turton highlighted the major changes South Africa was undergoing in terms of environmental legislation at the time.

> [I]t's very important if you go back to that time, that mind-set at the time. So at that point in time South Africa was undergoing quite major radical changes in its environmental legislation. The National Water Act was being promulgated and NEMA [National Environmental Management Act] had not yet been promulgated. (Turton 1:74)

> I think there were less barriers then than there are now. I think at that point in time, once again, there was an enormous optimism in the region. South Africa just became part of SADC and there was just an enormous optimism that was everywhere. (Dr Turton 1:92)

Dr Turton further highlighted a high level of optimism prevailing in South Africa in the early 2000s, relating to the newly established environmental legislations and how this optimism, coupled with the emerging discourse within reflexivity, would result in better water demand management to the benefit of society.

> [I]t was driven at the time by this enormous optimism that was starting to take place in South Africa, where we believed that this environmental legislation was going to make a difference. And on top of that, of course there was also this emerging concept within this reflexive discourse, that water demand management, if you could do better things with your water, if you could manage your demand better, then it was possible to get to a point of reflexivity where you would be able to start restoring natural environmental habitat and natural environmental functionality, at the same time still growing economies and still making people happy. (Turton 1:76)

Dr Schachtschneider also highlighted a national focus in her interview:

> Within Namibia and also within Southern African, the water demand management work was kind of at its height … And we had a whole review around water demand management in Namibia and so we made a point of looking at it for different sectors. (Schachtschneider 1:42)

In this context, the first two phases of the WARFSA were launched and it is against this backdrop, that research projects were implemented through the newly established WARFSA.

In the next section, a brief overview of the eight WARFSA projects is presented.

12.3.1 WARFSA Project number P02. Water demand management, natural resources reconstruction and adaptive capacity

Project Principal Investigator (PI): Dr Anthony Turton (interviewee) discussed this project.

The P02 project was one of the first projects funded through the newly established WARFSA in 2000, and "sought to develop a deeper understanding of the various social components of what is known as 'adaptive capacity' in order that this knowledge can be incorporated into Water Demand Management [WDM] strategies currently under consideration within the SADC region". (Turton, 2002)

According to Turton (2002), in constructing the project, three research areas were chosen in South Africa, Botswana and Zambia, which addressed a series of hypotheses based on three research topics:

1) an understanding of the role that legitimacy plays in WDM policies;
2) a deeper understanding of the respective components of any sustainable WDM policy within the cultural, political and economic context of Southern African; and

3) to further develop, and if possible, to operationalise, the intuitively useful but as yet largely untested concept of 'adaptive capacity'.

Through the study, a detailed cross-sectional understanding of eight sites in three different countries was provided (Turton, 2002).

The original impetus for the project P02 was driven by the perception that it was very topical at the time, and further supported by the optimism relating to the newly established IWRM paradigm, which was established in the SADC region.

> It [the project P02] was a very topical issue at that point in time and in fact, I'd like to think that it was actually pretty much cutting edge at that point in time of that particular policy kind of interface. (Turton 1:77)

> At that point in time, I was imbued by this enormous optimism, this new ideological paradigm that is coming out. The fact that we're going to work regionally. The fact that as South Africans we were now capable of tracking two areas that previously were not available to us, etcetera. So, it was just a lot of optimism. (Turton 1:83)

The project generated considerable data, which led to a follow-up project funded by the International Union for Conservation of Nature (IUCN).

12.3.2 WARFSA Project number P63. The application of satellite data for estimating flow characteristics of ungauged catchments

Project PI: Dr Dominic Mazvimavi (interviewee) discussed this matter.

Funded in the first Phase of the WARFSA, project P63 was primarily the PhD study of Prof. Mazvimavi (Mazvimavi, 2003). As per the dissertation, the study objectives were:

- to identify catchment characteristics that could be used for predicting flow characteristics of ungauged catchments;
- to examine the feasibility of using catchment characteristics for identifying catchments with similar hydrological responses or delimiting hydrologically homogenous regions;
- to assess the potential of using hydrologically homogenous regions as the basis for estimating flow characteristics of ungauged catchments;
- to determine the possibility for regionalising parameters of selected lumped rainfall-runoff models on the basis of catchment characteristics, and using these to estimate flow characteristics of ungauged catchments; and
- to assess whether neural networks have a better capability than multiple regression methods to predict flow characteristics and parameters of conceptual rainfall-runoff models from catchment characteristics.

The project resulted from a need to examine whether hydrological data about catchments in Zimbabwe could be generated from emerging data sources, given that very limited observed data did exist at the time (i.e. 2003). These emerging data sources came from colleagues at UNESCO working in Europe and from similar work on the same topic undertaken in the SADC region. In addition, Prof. Mazvimavi was working at the Zimbabwe Department of Water where a lack of data was always a problem.

The work has subsequently influenced various research projects in Zimbabwe, Botswana and Mozambique, where national water resource assessments were undertaken by Prof. Mazvimavi.

> Quite a lot of the work that I've been doing involves us using the techniques developed not only in research, but in doing national water resources assessments in Zimbabwe, Botswana, Mozambique (1:58).

12.3.3 WARFSA Project number P173. The private sector participation in the water and sanitation industry in Zambia: Opportunities and constraints

Project PI: Mr. Ian Banda (interviewee) discussed this project.

Project P173 was funded under Phase II of the WARFSA programme, with Mr Ian Banda as the project PI as part of his master's degree in Engineering at the University of Zambia. According to Banda (2004), the main objective of the study was to "investigate the appropriateness of private sector participation (PSP) service delivery arrangements as a means through which water supply and sanitation services may be rendered in Zambia, with the City of Lusaka being the test case, and to identify the associated opportunities and constraints". (Banda, 2004)

The impetus for the project emanated from an apparent curiosity as private sector participation in the water and sanitation sector in sub-Saharan Africa was a relatively new phenomenon at the time (i.e. 2004). This resulted in a need to understand this phenomenon from the Zambian perspective, as other countries already had some experiences. In addition, an apparent lack of knowledge on PSP in water and sanitation existed in Zambia, resulting in gaps and a need to have a deeper understanding of PSP in the Zambian water sector.

Immediately after the WARFSA-funded project, Dr Banda was appointed for a period of six years as the chief executive officer (CEO) of the second largest water utility in Zambia. Moreover, the study resulted in Dr Banda continuing with his PhD at the University of Cape Town on a topic that was closely related to his original work. He completed his PhD studies in 2013.

12.3.4 WARFSA Project number P191. Cestode parasites of the African sharptooth catfish, Clarias gariepinus, as bioaccumulation indicators of heavy-metal pollution in the Vaal River catchment area, South Africa

Project PI: Dr Annemarie Avenant-Oldewage (interviewee) was interviewed in this regard.

Funded during Phase II of the WARFSA programme, Project P191 originally started with the investigation of Cestode parasites of the African sharptooth catfish (*Clarias gariepinus*) as bioaccumulation indicators of heavy-metal pollution, but subsequently changed to the investigation of parasites in yellowfish (*Labeobarbus kimberleyensis*). The impetus for the project was an approach using bio-indicators from organisms found in largemouth and smallmouth yellowfish, to study the existence of pollutants in water, and resulted in an MSc dissertation (Retief, 2007) and various articles.

In many aspects, Prof. Avenant-Oldewage today regards this work as the cornerstone of her research.

> That was the first work of the kind that we did, and since then we've really advanced. So, the funding that we received from WARFSA really kick-started us into a new orbit with this kind of work. And we have now been able to come to very nice conclusions which has received a lot of international recognition as well, for using parasites as the sentinels for pollution. (1:14)

Today, Prof. Avenant-Oldewage oversees a large research team at the University of Johannesburg, and received various awards for her work, namely:

- an Innolec scholarship to the Czech Republic awarded by the Ministry of Education of the Czech Republic, September 2006;
- an invitation to lecture in Germany at University of Duisberg-Essen, with travel and accommodation sponsored by the German Minister of Education, September 2016; and
- an honorary medal in recognition of achievements and contributions towards the advancement and development of science from the South African Academy of Science and Art, June 2016.

12.3.5 WARFSA Project number P23. Water demand management study in Namibian tourism facilities **and** *WARFSA Project P 186: Subsurface water and riparian tree interactions in an ephemeral river*

Project PI: Dr Klaudia Schachtschneider (interviewee) discussed these projects.

As a young, novice researcher, Dr Schachtschneider undertook the first of two WARFSA-funded projects: WARFSA project P23, within Phase I of the WARFSA programme, while working at the Namibian Department of Water Affairs.

The original objectives of the study were to:

1) provide a water demand management (WDM) strategy for the Namibian tourism sector in accordance with new policies published, and
2) implement and test suitable water conservation measures for the industry, which would result in increased water use efficiency at tourist facilities in Namibia (Schachtschneider, 2001).

The impetus for the project was a review of WDM in Namibia with the topic having prominence in the country.

> I was working in a research capacity at the Department of Water Affairs, and the water demand management was a massive topic at that point in time [i.e. 2001]. Within Namibia and also within Southern Africa, the water demand management work was kind of at its height. And we had a whole review around water demand management in Namibia and so we made a point of looking at it for different sectors. (1:41)

From the project report, it was clear that various stakeholders were consulted in workshops, with a guidelines booklet published at the end of the project. The project resulted in her MSc (Schachtschneider, 2002).

The second of Dr Schachtschneider's WARFSA funded projects (P186) was undertaken within the concluding stages of Phase II of WARFSA, and resulted in Dr Schachtschneider's PhD (Schachtschneider, 2010).

12.3.6 WARFSA Project number P232. Plant extracts to improve ground water quality in shallow wells

Project PI: Dr Theresa Mkandawire (interviewee) was consulted in this regard.

Working in close collaboration with researchers in Leeds Metropolitan University in the United Kingdom, Dr Mkandawire received initial funding for WARFSA project P232 in the latter part of Phase II of the WARFSA programme. The project was part of her PhD (Mkandawire, 2012), which she obtained from Leeds Metropolitan University.

As part of a larger study project at Leeds Metropolitan University, project P232 analysed the shallow well drinking water quality of 17 000 rural wells in Malawi, with data being fed into the Water Resources Investment Strategy, which aided the development of policy (Leeds Metropolitan University, 2014). The original motivation for the project was to generate data on the water quality of shallow wells, and to develop novel technology to use plant extracts to improve the quality of water in shallow wells.

Outputs from the project are the development of a new MSc course at the University of Malawi, while workshops and fieldtrips integrated the research into undergraduate curricula. In addition, a sustainable natural water purification system has been developed to reduce contaminants (up to 80%) at source.

12.3.7 WARFSA Project number P148. Linking water and livelihoods: The development of an integrated wetland rehabilitation plan in the communal areas of the Sand River catchment as a test case

The project PI was Dr Sharon Pollard, but the researcher, Prof. Graham Jewitt, was the interviewee.

Prof. Graham Jewitt was the researcher focussing on the hydrology aspects of project P148, which was funded in the early 2000s and in Phase II of the WARFSA programme. At the time in the late 1990s and early 2000s, large-scale development was taking place in the Sand River catchment in the Lowveld, South Africa, with a high population density for a rural area. In addition, the Craigieburn wetland (Mpumalanga, South Africa) in the catchment was heavily utilised by people for supplementary food production, particularly crops. The incentive for the project thus stemmed from a need to understand which rehabilitation could take place in the Craigieburn wetland due to the increased cultivation in the area. In addition, the project assessed what the impact would be on the rural livelihoods of the people who used the wetland, as no previous research had been undertaken in the Craigieburn wetland at the time. This had to be based on a strong biophysical basis in terms of understanding and mapping the wetland function.

Today, WARFSA funding for project P148 is seen as seed funding, which has subsequently resulted in the area being established as a long-term environmental research (LTER) site and which influenced various research projects and knowledge of the area over the past 11 years (Riddell, Thibela, Lamula & Swemmer, 2016).

> Yes, and I think that was a benefit of the WARFSA project. Because the reality is the funding was very small. There was never a big funding project and it was always sort of linked to small projects and student projects. So, effectively it was a very good seed fund. (Jewitt 1:99).

12.3.8 WARFSA Project number P221. An assessment of the level and effect of pollution along the shoreline of Sanyati Basin (Lake Kariba): An opportunity to develop bio-assessment for detecting pollution

Project PI: Dr Crispin Phiri (interviewee) discussed this project.

WARFSA Project P221 was funded in the mid-2000s, during Phase II of the WARFSA programme, with Dr Phiri as the principal investigator of the project. The objective of the project was to assess the level and effect of human activities on communities in the shallow marginal water (within 500 meters from the shoreline) of the Sanyati Basin of Lake Kariba. This was done through the selection of thirteen sites, which were sampled in 2005, with human activity categorised through a scoring system. In addition, water samples were collected and several physiochemical variables analysed. In addition, the percentage cover of emergent, floating and submerged aquatic vegetation was measured within 100 meters of each site, with submerged vegetation sampled for periphyton and macroinvertebrates (Phiri et al., 2006).

Funding from WARFSA was acknowledged as seed funding to start the project, which resulted in a PhD at the University of Cape Town (Phiri, 2010).

12.4 Cross-case analysis

Through an analysis of the coded interviews, various cross-case themes became apparent, which are discussed in more detail.

12.4.1 Two communities

Caplan (1977; 1979) presents the two communities theory, which states that scientists are concerned with ‘pure’ science while, by contrast, policymakers are ‘action-orientated, practical persons concerned with obvious and immediate issues’. According to Caplan (1979), this creates a gap between the knowledge producers and policymakers. Many factors could contribute towards this gap between the research community and policymakers, some of which were evident through the interviews with the WARFSA-funded researchers and stakeholders.

The gap between the research community and policymakers can be at an ideological level, where the priorities of researchers and policymakers do not align:

> [A]t local level, I think there’s massive barriers to policy now and that’s because of the politics in the country, with the slow deterioration or degradation of the politics in the country to the point where everything is so highly politicised that if you’re just a technical specialist you tend be ignored because you’re not ideologically part of the in-crowd. (Turton 1:90)

> [O]ver time […] the South African policy space in my view has become totally dysfunctional now and I know of very little evidence-based policy that's being taken up into the scientific community. (Turton 1:90)

Government structures, especially at a regional level, could create barriers, causing researchers to feel they have access to ministers and not the policymakers themselves:

> So, we [South Africa] often find that our research influences policy in water and sanitation quite effectively. In the region that's a little bit more difficult. And particularly at SADC level because you're actually removed from decision-makers […] So, it's very rare that you actually deal one on one with the government officials who are the policymakers and implementers. And in some ways you actually have more access to the ministers. But the ministers don't actually make policy all that much. You've gotta find the right channel through their government departments to do that, and at an SADC level that's very difficult. (Jewitt 1:106).

Moreover, to an extent, competition might exist amongst researchers and policymakers creating barriers:

> But I think that, in many instances, just like I said, people that sit in governments and places think that you are competitors and so they try and keep you at bay. Like even in some of the works that they should be doing and they should acknowledge it, they don't […] directly. But when they sit there, they use that as something that comes from themselves and so that keeps a barrier between academia and policy. (Nkhuwa 1:39)

Even though, at the project selection stage, mechanisms were put in place by the WARFSA board to encourage policy uptake in the research projects, policy outcomes did not necessarily materialise.

> In terms of project selection, I think there was a criteria, I can't remember the detail now, whether the proposal or the research work would contribute to policy. It was really a passive way that we implemented, because I don't remember any policy initiatives that came as a result of the research that we had conducted. (Sanyanga 3:2)

Evidence exists from the interviews that the primary focus of the WARFSA-funded projects were on research capacity development as appose to policy uptake.

> The policy issues were an afterthought. (Phiri 1:10)

> For most people, it was an academic exercise. It assisted them in acquiring either their master's research requirements or publications towards their careers. And well, that is good, it's a contribution, it equipped them with that education … WARFSA mainly served to provide a source of funding for research. (Sanyanga 3:7)

Factors that further contributed to the gap between policymakers and the research community are a sense that policymakers and practitioners were ill equipped to understand and implement issues, which actually provided an opportunity for the researchers.

> [A] lot of the people who are responsible in implementation, formulation and implementation have a very, very shallow understanding of these approaches to service delivery, like public–private partnerships. For example, you find that government officials don't even know what is the difference between a management contract and a lease contract, a lease contract and a service contract. They don't understand. And yet they parrot this terminology at public fora, but they don't have an in-depth understanding. That's why it's important that in the country you have several individuals who are trained, who have an understanding, so they can give proper guidance. (Banda 1:33)

Moreover, it was perceived that policymakers did not seek input from researchers:

> [P]olicymakers, sometimes they don't seek research findings or find out what is happening. Their policy decisions are not informed by any research, but more by political desire or certain drivers which I can't define. (Sanyanga 3:10)

> Maybe at country level, is research appreciated? Do we really encourage good research and is it appreciated? (Dr Banda 1:34)

On the other hand, evidence exists that researchers themselves could have been responsible for creating a research–policy gap by not disseminating research to policymaker and practitioners.

> [I]n many instances, there was no, I think there's still no compassion from the research institutions to go out and share their findings with maybe people from the policy domain. To a great extent, research, I think, has been used basically to produce papers, do your publications and then we include them, I mean on CVs, and people go into promotions. (Nkhuwa 1:37)

> The outputs are mostly communicated in peer-review journals and I think it was last week, somebody was saying that those journals are hardly read by policymakers. Unless it's something like in the medical world where it's something that is of very high impact that it changes the practice. But in most cases our communication channels are through peer-review journals, which are not accessible to the general public. (Mazvimavi 1:65)

> But when you don't have such mechanisms, when you write and publish in the very distinct journals, sometimes some of the things, they just remain buried in there. So again, here in this part of the world, it becomes again a problem that is we have got a narrow base. The number of people who are into practice and who are accessing scientific material, they are going to be very small. (Mazvimavi 1:67)

> Researchers, on the other hand, have not figured how to feed into policy or are not aware that they could contribute effectively to policy decisions. (Sanyanga 3:10)

Moreover, a lack of deliberate action and strategy from a programme implementation perspective to support the broader dissemination of research to policymakers and practitioners, further contributed to a gap between policymaker and researchers.

> [I]f there's no deliberate or intentional way of moving up the research findings to policy level or disseminating them and encouraging uptake by say service providers, water activities and so forth, it ends up being like shelf report, shelf theses and so forth. I think we fell into that same category where the information uptake, dissemination, was not deliberately targeted. There was no uptake strategy, there was no institution targeted to do that bridging of the gap from the researchers to implementers or to users of that work. (Sanyanga 3:6)

> In terms of aspects of policy, of implementation, of how that research goes further, we lacked that strategy. We didn't have a strategy. (Sanyanga 3:7)

A lack of funding further contributed in various ways towards research not being disseminated; thus, contributing to a gap between policymakers and researchers, where research had to be stopped.

> [F]unding, it discontinued. So, barely two disbursements into the funding, then it stopped. It was a huge blow and it delayed my PhD study … So, I had to stop my work and start writing proposals again. (Mkandawire 2:12)

About efforts in disseminating research, it was said:

> [L]et's say we had to continue it with sufficient funding, there would be a place like something like a waterwheel that would be something that is readily accessible to the practitioners. (Mazvimavi 1:68)

> We didn't have a strategy [for dissemination], but perhaps we also even didn't have the [financial] sources to do that. (Sanyanga 3:7).

> The funding ran out. The one year's funding was actually quite a mission to get hold of eventually, because I think there was some administrative reason to get the last year's funding. (Prof. Avenant-Oldewage 1:17)

Regarding follow-up aspects, this view was expressed:

> I think people […] because the follow-on aspect would not come through and the follow-on aspect will basically […] whether or not it gets funding. Because the follow-on aspects actually, I actually didn't even got any funding for the follow-on aspect. (Dr Phiri 1:9)

Moreover, with limited financial resources not making it easier for young researchers –

> [F]unding is critical, especially when you look at supporting the young scientists. (Dr Mazvimavi 1:71)

> The availability of funding for people who are senior like myself, it's a constraint, but not a great constraint. But at the lower level, where we want to grow, that's where the constraint is. (Dr Mazvimavi 1:72)

The WARFSA initiative further had an objective to support novice researchers (WARFSA, 2005). Evidence was found that these young scientists could have a sense of being undermined when it comes to influencing policies, which contributes to a gap between researchers and policymakers.

> [B]eing a junior researcher and not having the clout to have the impact. (Schachtschneider 1:53)

12.4.2 Discussion: Bridging the gap

In the previous section, evidence was provided of the two-communities theory and the apparent gap that existed between the WARFSA-funded researchers and the policy community. There are various ways in which this gap can be bridged, namely the establishment of personal relationships, which involves characteristics such as trust, confidence and empathy (Caplan, 1979), or where research creeps or percolates into the policymaking process (Weiss, 1977). However, as was evident in the previous section, it was not always the main objective of WARFSA-funded research projects to influence policy or practice. Research however was not undertaken in isolation from policymakers or practitioners, with these stakeholders often involved in projects to a certain extent.

In this section, various themes are discussed which were evident from the interviews, and which relate to efforts to bridge the apparent gap between policymakers and practitioners and the research community. These themes are

- the involvement of policymakers and practitioners in the research projects;
- the dissemination and translation of research findings into policy and practice; and
- intermediaries and knowledge brokers who enable the uptake of research into policy and practice.

12.4.2.1 Involvement of practitioners and policymakers in the research projects

Throughout the research process, researchers as well as policymakers and practitioners can engage with each other (Buxton & Hanney, 1996; Donovan & Hanney, 2011). In the interactive model, Weiss (1979) describes how, through a non-linear process, inputs such as experience, judgement, political insight and pressure provide inputs into the policymaking process. Weiss states that these inputs are provided by various role players, namely administrators, practitioners, politicians, planners, clients, interest groups, aids, friends, social scientists and journalists. These role players provide a pool of talents, beliefs and understanding, which could be accessed progressively in order to address the problem, and form part of a complicated process, which includes experience, political insight, pressure, social technologies and judgement. Moreover, as a conceptual use of research, research creeps, or as Weiss (1977) states, percolates, into the policymaking process.

Engagement between researchers and policymakers or practitioners could take place in the early stages of a research project where research could support predetermined positions in order to increase the credibility and acceptance of decisions as in the case of the political model (Weiss, 1979). Lindquist (1990) presents the existence of a 'third community' inside and outside of government, who does not necessarily comprise policymakers or organisations, but who are committed to providing policy-relevant data, research and analysis, and thus influencing high-level decision-making. This notion of outside organisations lobbying legislature policymakers to influence policy decisions, is also put forward by Rich (1990) Moreover, as Etzkowitz and Leydesdorff (1998) argue when presenting the triple helix model, innovation is enhanced through the spiral effect, where universities-government-industry engage with each other throughout the research process. In the interviews, the South African Water Research Commission (WRC) was indicated as such an agency.

> More generally, on policy, particularly South Africa, the [researchers] are quite well connected with policymakers through the Water Research Commission, steering committees and through various events. So, we often find that our research influences policy in water and sanitation quite effectively. (Prof. Jewitt 1:105)

The WRC uses communication media such as *WaterWheel*, a magazine aimed at policymakers and practitioners to communicate research, which was also mentioned by Prof. Mazvimavi in his interview:

> [I]n South Africa, you usually see the Water Research Commission, they actually try to improve this. Like that *WaterWheel*, which is sort of a form in which results from research can be communicated to people and that arouses their interest. (Prof. Mazvimavi 1:67)

Moreover, change agents could play a role in influencing policy or practice. These change agents could be people who change careers from inside government to outside government (and vice versa), as suggested by Lindquist (2001) and by Havelock (1969:10–53) who argues that from a problem-solver perspective, both receivers and external "change agents" work together – change agents being individuals or groups having the resources to assist receivers to bring about change. Imperative though, that even if the change process is initiated by the receiver or change agent, the receiver must have the desire to change and must participate fully in bringing about the change.

From the interviews, evidence of the above-mentioned factors was found, which related to the WARFSA-funded research projects. In Dr Banda's case, research emanated from interest on the side of the German government through GTZ[45] who were involved in the Zambian water sector in the early 2000s, and which is an example of where the interest in a specific research topic emanated as part of the intellectual enterprise of society, where various societal stakeholders have an interest (Weiss, 1979).

> In fact, when I started my research and the GTZ water sector, the German government-supported water sector heard about it, they actually asked me to conduct some research. (Dr Banda 1:28)

Moreover, Dr Mazvimavi's was working at the Zimbabwe Department of Water on his research project and realised that the research would address gaps in data, which could influence policy in the future – an example of research resulting from the identification of a research problem.

> It's an issue that we have discussed for quite a long time in the Department of Water and requiring attention. (Dr Mazvimavi 1:59)

Often, researchers are tactical in the identification of participants in research projects, as Dr Turton who carefully selected local role players who could potentially influence policymakers, and further act as change agents in future.

> But, basically, I selected local participants, very carefully selected. So, in each country I had a, like a project leader in each country, and then they had a team of people. The whole idea was to teach them the skill to go out and actually do the survey, 'cause it really was a people-intensive survey in the different areas. And the people that were selected in that process came from a wide variety of locations and some of them were in fact in the policy field. They were either government functionaries or they were people from other organisations. For example, in Zambia I linked up there with a sort of CSIR equivalent in Zambia. (Dr Turton 1:81)

In the case of Dr Mkandawire, engagement with the Ministry of Irrigation and Water Development was initiated before the project was conducted, which potentially would assist in the uptake of the research.

> Yes. So, when I finalised the topic with my supervisor, before I embarked on the project, I had to write the Ministry of Irrigation and Water Development. Initially, I wrote them so that they would give me a supervisor at a local level. That did not work out. (Dr Mkandawire 2:6)

Not all respondents involved policymakers in the actual selection of the research project, as in the case of Dr Schachtschneider (1:46), Dr Phiri (1:5) and Prof. Avenant-Oldewage (1:16).

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[45] Note that in 2011, the Deutshe Gesellschaft für Technische Zusammenarbeit (GTZ), changed its name to Gesellschaft für International Zusammenarbeit (GIZ) (see Panapress: 2011).

Apart from involving policymakers and practitioners in the early stages of their research projects, evidence was found of respondents who involved practitioners and policymakers in various capacities *during* their research projects. Dr Schachtschneider (1:47), while working in the Namibian Department of Water Affairs, involved the Namibian Director of Water Affairs in the steering committee of the research project, which led to the department being aware of the project.

> [A]nd so did the Director of Water Affairs. So, there was certainly knowledge of what was going on (Dr Schachtschneider 1:47)

As indicated earlier, Dr Turton (1:81) not only carefully selected local participants in the selection of the project, but also during the execution of the project, who were involved in various levels of government.

> [T]he people that we had in the team were all either very well known or very respected within their communities and they were certainly integrated into various parts of government. The Botswana guy was in fact a service provider to some of the Botswana Department of Water Affairs projects. So, he was very well known within the department. I think, if I remember correctly, the way we targeted the people that we spoke to as well, there was a very specific stratified sampling … we targeted individual people for specific reasons. (Dr Turton 1:82)

Prof. Avenant-Oldewage also involved a practitioner from Rand Water (a major water utility) during her project.

> Yes. The third person in the project was Hein du Preez. He is the head of the analytical services of Rand Water (Prof. Avenant-Oldewage 1:15).

Dr Mkandawire indicated the involvement of the Malawian Ministry of Water and water monitoring assistants during the project.

> But when I embarked on the study, I made contact with the ministry again to guide me in terms of where these points were. So I wrote [to] the ministry and then I was given an okay. So, I was working with the water monitoring assistants in the districts … So, every visit I'd make a prior arrangement with the ministry and they would give me someone to work with in that district and that person would be the one guiding me, showing me where these shallow wells are. So yes, the policymakers were involved in this regard (Dr Mkandawire 2:7).

Some respondent indicated that they did not involve practitioners or policymakers directly in their projects, such as Dr Phiri and Dr Mazvimavi.

> So, the policymakers, as well as other stakeholders, did not have much input in terms of the project itself […] I got into that later on. But, otherwise, during the project, I was more of an academic, trying to feed into policy with regard to water. (Dr Phiri 1:5)

> Well, no not directly in the project. (Dr Mazvimavi 1:60)

12.4.2.2 Dissemination and translation of research findings into policy and practice

From the literature review reported on in Chapter 4, it was evident that research utilisation comprises various stages, that the dissemination of research on its own is not enough to translate the research into practice or policy uptake, and that various levels of utilisation exist in which each level is a link in the process of utilisation (Knott & Wildavsky, 1980; Landry et al., 2001a; 2001b). Only when evidence exists where research is being referenced or cited, and a specific effort is made to translate research into policy or practice does research translate into the adoption and influence of the choices and decisions.

Knott and Wildavsky (1980) further argue that there are at least three obstacles that limit the use of knowledge by decision-makers. These obstacles are

- the knowledge does not exist;
- where information does exist, decision-makers are ignorant about the knowledge; and
- the decision-makers know about the knowledge, but refuse to use it (Knott & Wildavsky 1980:541).

Dr Banda's comments reflect these sentiments:

> [Y]ou need an enabling environment for people's research findings to be disseminated and also consumed by those who need it … when you look at the water and sanitation sector, it starts first with political will at national level, because the issue that we are talking about have got serious implications on government policy. So, you need to have an enabling environment and political will from the policy formulators and that is government, first and foremost. (Dr Banda 1:32).

Knott and Wildavsky (1980) further discuss the relationship between research utilisation and dissemination, and state that if one could determine whether and in which way underutilisation of information is a problem, then one could address the challenges relating to the dissemination of research. The authors argue that there is a school of thought, which argues that utilisation refers to the immediate and direct influence of a major research project on a policy. Others, again, believe that research utilisation refers to the long-term process in which accumulated results of research over time enlighten policy (for example Weiss's enlightenment model [1979]). Knott and Wildavsky (1980:573) argue that dissemination could be a solution to underutilisation **if** the knowledge is disseminated to specific people under specific circumstances. They further argue that premature dissemination in the absence of knowledge could contribute to an overload of information, thus making dissemination a potential cause to the underutilisation of knowledge.

From the interviews, evidence was found that research dissemination to policymakers and practitioners could be in various formats, and it could be disseminated directly or indirectly. In Dr Phiri's case, research was disseminated, and subsequently influenced his involvement in Zimbabwe's 5th National Report to the Convention on Biological Diversity (from his CV and confirmed during the interview) and further as chapters in a book (see Phiri & Mhlanga, 2014; Mhlanga, Phiri & Chifamba, 2014) which influenced his involvement in the National Report.

> [It] influenced my involvement within the working group. And also I was involved in a book on Kariba … I think I wrote two chapters in that book. (Dr Phiri 1:6)

Dr Mazvimavi (1:62) whose work in the Zimbabwe Department of Water inevitably led to the department being aware of the research added:

> I used to also do quite a bit of work for the department. So, inevitably, they would be aware of what is going on. (Dr Mazvimavi 1:62)

As indicated earlier, by further targeting very specific people to participate in the project, Dr Turton (1:82) realised that the research would be trusted and disseminated to policymakers.

> [T]he people that we had in the team were all either very well known or very respected within their communities and they were certainly integrated into various parts of government. (Dr Turton 1:82)

Dr Mkandawire also reported that the involvement in the project at least made them aware of the project.

On my question whether participation in the project might contribute towards eventual uptake, she said:

> Yes, I would say so. Because they were involved, they knew the existence of the project and then I shared with them the data. So, it's easier to understand something that you've been involved with because they were aware all through the process. (Dr Mkandawire 2:8)

In addition, by specifically communicating research findings to the ministry, Dr Mkandawire was able to influence the use of her research:

> [T]he papers that I published were sent to the ministry. So, when they were revising, working on their strategy document, they made reference to that. So, most of the information was from my research … So, my research fed into that. So, they used part of my findings in that water strategy document. (Dr Mkandawire 2:5)

In addition to the above-mentioned experiences, Dr Schachtschneider highlighted the effectiveness of personal relationships with policymakers in research dissemination, and remarked that the relevance and timing of disseminating research were deemed important by policymakers and the research

> Personal relationships with key policymakers I think has something to do with it. And also the kind of politics of the field. […] strike while the iron is hot. If there is a debate about it, make sure that your policy comments go in […] And you need to speak to the right people in order to have your policy points taken up […] it depends as much on what you know as well as to get it taken up. (Dr Schachtschneider 1:50)

Should one consider the progressive nature of the standards and stages of utilisation as presented by Knott and Wildavsky (1980) and Landry et al. (2001a, 2001b), the dissemination of research is but a stage in the translation of research into policy and practice. As indicated earlier, policymakers and practitioners are required to read and understand the research and digest the content of it, in order for them to change their mind-set effectively and actually use and cite the research in reports, studies and strategies. Using the research further requires effort to adopt the results and making the effort to implement policy change successfully or unsuccessfully, which finally influences the adoption of policy outcomes. This process could typically take quite a few years, with a major challenge arising – attribution.

12.4.2.3 The attribution of research findings to policy impact

Key to associating research work to research translation, is attribution (or contribution) (Buxton, 2011; Spaapen & Van Drooge, 2011) – the way a researcher could link the formulation of policy or a change in practice to a specific research project or a set of associated projects (Bell et al., 2011; Donovan, 2011; Huberman, 1994). Without corroborating evidence that research dissemination translated into policy or practice, researchers have difficulty in claiming that their research, as a broader body of knowledge, shaped policy formulation.

As indicated in the previous section, researchers are sometimes aware of their research being used in the development of policy or strategy documents. During the interviews, interviewees were asked whether they knew if their research had been cited in policy documents, and without exception, interviewees indicated that they were unaware – they might be aware of its use, but not the physical citing of the research. Generally, researchers are increasingly aware of citations from scientific peer-reviewed journals as captured in citation databases such as Scopus and Web of Science. With more recent developments in Webometric tools such as Google Scholar, which create citation scores broader than the scientific peer-reviewed journals, scholars might however find themselves in future being aware of reports citing their work beyond what is captured in journal citation databases such as WoS and Scopus.

There are however mechanisms in frameworks, such as the United Kingdom's Research Excellence Framework (UK-REF), which specifically requests researchers to provide sources of such corroborating evidence. In WARFSA project P232, research collaborators from Leeds Metropolitan University reported in the UK-REF (Leeds Metropolitan University, 2014):

> Water Officers in Malawi have used this data to select which wells should be directed towards supplying drinking water or providing water for washing.
>
> Data from this study has been fed into the Water Resources Investment Strategy, Component 1 – Water Resources Assessment of the Government of the Republic of Malawi Ministry of Irrigation (Leeds Metropolitan University, 2014).

Such corroborating evidence, however, requires researchers to monitor research output continuously through programme coordinators' surveys as proposed by Guinea et al. (2015).

In addition, and as indicated in the interview with Dr. Sanyanga, the WARFSA-programme lacked a specific strategy for the dissemination of research

> [I]f there's no deliberate or intentional way of moving up the research findings to policy level or disseminating them and encouraging uptake by say service providers, water activities and so forth, it ends up being like shelf report, shelf theses and so forth. I think we fell into that same category where the information uptake, dissemination, was not deliberately targeted. There was no uptake strategy, there was no institution targeted to do that bridging of the gap from the researchers to implementers or to users of that work. (Sanyanga 3:6)
>
> In terms of aspects of policy, of implementation, of how that research goes further, we lacked that strategy. We didn't have a strategy. (Sanyanga 3:7)

This is not to say that WARFSA-funded research was not disseminated to policymakers or that practitioners did not receive the research, as in the case of Dr Schachtschneider where a booklet for the tourism industry was produced:

> There was a little booklet that came out particularly for the tourism industry and that was available to various lodges and whoever, tourist facilities, with different water-saving tips. So, that was some very practical tips. (Schachtschneider 1:44)

There were some policy recommendations in her thesis and project reports:

> [T]he policy recommendations would have come into my thesis, or one of the final reports as a section. (Schachtschneider 1:45)

She was however clear that these recommendations did not translate into policy:

> But, it was not actually translated into overall policy in the end, no. (Schachtschneider 1:45)

This might have been the result of her being a junior researcher in the WARFSA programme:

> I think policy uptake in our case would have been overtly one of being a junior researcher and not having the clout to have the impact … It's a matter of networking and which stakeholders you know, and those are particularly linking to the ones who can make a policy decision … they are very often the ones that are also not even interested in speaking to a junior scientist that might be WARFSA-funded. (Dr Schachtschneider 1:53)

From the interviews, there was evidence of the outputs from the research translating into policy and/or practice, such as when Prof. Mazvimavi who indicated that his work translated into policy and practitioner uptake:

> [T]he guideline for water resource assessment of Zimbabwe now, the current guideline that they use, it's actually, you could say it's based on that work that we did … Prior to that, there's some work that has been done but as soon as we finished, the government and with UNDP, they asked us to re-evaluate the available water resources in Zimbabwe. (Prof. Mazvimavi 1:64)

Dr Banda personally put the knowledge he gained from the WARFSA-funded research into practice when he was appointed CEO of a water utility in Zambia:

> [T]he impact is more or less a better understanding and for me, soon after I think my master's, I became a chief executive officer of the water utility, the biggest, the second largest utility in Zambia. So, that knowledge I gained helped me as I worked in this utility where I was CEO for six years. (Dr Banda 1:26*)*

For researchers such as Prof. Avenant-Oldewage, the WARFSA funded research was an initial project, which personally led to further research:

> That was the first work of the kind that we did, and since then we've really advanced. So, the funding that we received from WARFSA really kick-started us into a new orbit with this kind of work. And we have now been able to come to very nice conclusions which has received a lot of international recognition as well, for using parasites as the sentinels for pollution. (Prof. Avenant-Oldewage 1:14)

Prof. Avenant-Oldewage also incorporated her research into post-graduate courses and short learning programmes for practitioners:

> What I did is, it's of course been incorporated in courses that I teach on honours level and then I also do a short learning programme for water practitioners, which is mostly the environmental assessment consultants. (Prof. Avenant-Oldewage 1:18)

In Prof. Avenant-Oldewage's case, some of her research eventually contributed towards policy formulation:

> The health assessment index, which incorporates the parasite, has gone into policy, in the policy about environmental impact assessment. (Prof. Avenant-Oldewage 1:21)

Dr Turton's research also did not initially result in any policy or practitioner uptake:

> I'm not sure if at the end I've ever used it any further, but certainly at that point in time there was a lot of data collected. (Dr Turton 1:79)

However, Dr Turton's research eventually influenced policy through a project, which resulted from his initial WARFSA-funded project:

On my remark that the project on water demand management as a concept and policy which creates a set of guidelines for Southern Africa followed the initial WARFSA-funded project, Dr Turton responded

> Yes. That was a project that followed on from the WARFSA project. (Dr Turton 1:80)

Much like Prof. Avenant-Oldewage and Dr Turton, Prof. Jewitt's WARFSA-funded research was the start of a long-term research project, which only later influenced policymakers.

> [T]here was quite a lot of useful information that came out, not so much directly from the WARFSA project but a little bit later when the natural resource management and the WRC bought into that catchment. So, it led to policy around the use of wetlands by people and how to rehabilitate and use those wetlands at the same time. (Prof. Jewitt 1:100)

It is thus evident that the translation of research into policy and/or practice does not necessarily result from one research project, but often spans several research projects and results over time. Unless researchers personally have knowledge of research influencing policies or guidelines, the attribution of research findings is challenging.

12.4.2.4 Intermediaries and knowledge brokers

From the interviews, the role of intermediaries, in various formats, to bridge the gap between researchers and policymakers became apparent. Such knowledge brokers (Lavis et al., 2003; Van Kammen et al., 2006) could be people who have changed careers from inside government to outside government (and *vice versa*) (Lindquist, 2001) or in the form of outside organisations (Rich, 1990).

Outside organisations could have a clear mandate to initiate research with the aim to provide policy interventions, such as the South African Water Research Commission (WRC).

> More generally, on policy, particularly South Africa, the researchers are quite well connected with policymakers through the Water Research Commission, steering committees and through various events. So, we often find that our research influences policy in water and sanitation quite effectively. (Prof. Jewitt 1:105)

> [I]n South Africa, you usually see the water research commission, they actually try to improve this. Like that *WaterWheel*, which is sort of a form in which results from research can be communicated to people and that arouses their interest. (Dr Mazvimavi 1:67)

The South African WRC and the WaterWheel publication create a link between researchers and policymakers and practitioners and act as an intermediary between researchers and policymakers and practitioners.

Governments themselves often have structures through which researchers could channel their research:

> [I]t could actually be improved using even the SADC structures, the technical committees. (Dr Mazvimavi 1:69)

Moreover, individuals work within departments in government and act as intermediaries, often based on personal relationships and trust towards the researchers:

> I know Naomi Fourie and the guys in that directorate very well and they often phone for advice. Similarly with biofuels. The work that we did on, the stuff that's written into policy, they picked up from that project and being part of it and the final reports.
>
> So, because the people who are in charge of writing that policy and implementing it are part of the steering committee, it's quite effective. Because those policies are written, as I said, not by the ministers … there's a channel through the department to the DDGs [Deputy Director Generals] and to the DGs [Director Generals] and eventually the minister signs it into policy (Prof. Jewitt 1:108)

Apart from outside organisations, which have a clear mandate to use research to influence policy and practice, other platforms could provide such an opportunity. As discussed in previous chapters, the WARFSA programme was part of the annual WaterNet/WARFSA/GWP SA symposium, which, after seventeen years, is still active, and aims to provide a platform for researchers to present their research to a like-mined scientific community,

> [T]hat conference has always drawn people beyond academia. So, it's quite useful. (Prof. Jewitt 1:109)
>
> [B]eing a young researcher, the annual conferences that were co-created through WARFSA and WaterNet [were] extremely, extremely valuable networking opportunities. We really got to understand who they key water or some of the key water players are in Southern Africa and that was really fantastic. (Dr Schachtschneider 1:51)

The annual symposium and associated organisers such as the Global Water Partnership (GWP) further provide a platform for policymakers and practitioners to have access to the research.

On my question whether the symposium also played a role to disseminate the information to policymakers or practitioners at the time, one answer was:

> Yes, it did. (Sanyanga 3:5)
>
> [D]uring the symposium [there] were those who would have sessions and GWP was facilitating some of the stakeholders attending those symposiums. So, in that way you then have an improved sort of communication of the science to the practitioners. (Dr Mazvimavi 1:66)

Policymakers and practitioners normally participate in parallel sessions during the symposium, which provide opportunity, without guarantees, for researchers to interact with policymakers during the sessions:

> It was highly educational to understand the issues in the area but you were obviously not going to meet all the movers and shakers in the government positions necessarily. Because whether they attend was another matter and certain politicians would take it seriously, while others wouldn't. So, there was no guarantee on that, but you would certainly get a good understanding of what was essential in the area on a policy level. (Dr Schachtschneider 1:52)

This highlighted the need for researchers to use other dissemination channels to communicate their research as discussed in the previous section.

12.5 Conclusion

Through a systematic process, researchers and stakeholders from WARFSA-funded research projects were interviewed, with qualitative data coded in order to analyse themes. In addition, aspects such as the dissemination and translation of research into policy and practice, and intermediaries and knowledge brokers who play a role in bridging the gap between researchers and policymakers and practitioners were analysed.

First, a heightened level of optimism and progressiveness was prevalent in relation to water research in the early 2000s. This, coupled with the initial implementation of integrated water management at the SADC regional level, provided for an ideal backdrop for the implementation of the WARFSA programme.

From the interviews and analysis, evidence was found that two communities exist in the SADC water sector with, on the one hand, the research community and, on the other hand, policymakers and practitioners, giving rise to the development of a gap between the two communities. Within the WARFSA programme, the two communities were also prevalent, even though mechanisms were put in place during the project selection phase to bridge a potential gap between the two communities. According to the interviews, evidence however exists that the main focus of the WARFSA programme was to fund research capacity development as appose to policy uptake.

Factors, which contributed to the gap between policymakers and the researchers, were a sense that policymakers and practitioners were ill equipped to understand and implement research, and that policymakers did not seek input from researchers. Researchers themselves did not necessarily disseminate research to policymakers and practitioners, due to a lack of a deliberate action or strategy from the programme implementation perspective. Moreover, a lack of funding deterred researchers from disseminate research, with novice researchers sometimes experiencing difficulty in accessing policymakers and hindered by a lack of financial resources.

In bridging the gap between the two communities, evidence exists that researchers involved policymakers and practitioners at the selection of projects and during the research projects. From the interviews, it was apparent that even though the WARFSA-funded research primarily focussed on development of the researcher’s capacity, research outputs were produced from the research, which were disseminated to practitioners. Dissemination of research outputs did occur to policymakers, which in some cases influenced policy. Often, this happened as a result of subsequent projects and over time through other projects, but originated from the initial WARFSA-funded research.

Intermediaries and knowledge brokers were prevalent throughout the SADC water sector, with individuals and government departments playing a role. Moreover, in terms of the WARFSA-funded research projects, the annual WaterNet/WARFSA/GWP SA symposium, along with implementing agents such as WaterNet and GWP, still provides a platform for researchers, policymakers and practitioners to interact.

Chapter 13

RESULTS, CONCLUSIONS AND RECOMMENDATIONS

13.1 Introduction

At the outset of this study (see section 1.3), the following hypotheses were identified:

- The WARFSA programme increased research publications.
- The WARFSA programme increased the visibility of SADC publications.
- The WARFSA programme increased the use of research by policymakers.

Through a systematic process, relevant aspects were investigated and presented in three parts, with Part A providing the theoretical framework and research methodology of the research project, followed by Part B, which presented a sector analysis of the SADC water sector and further highlighted the institutional landscape of the SADC water sector and bibliometric analysis of water research in the SADC region. Finally, Part C of this study presented an analysis of knowledge production and findings related to the policy and practitioner uptake of research projects funded through Phase I and II of the Water Research Fund for Southern Africa (WARFSA).

This chapter highlights results of the study based on the hypotheses (see section 13.2), and the doctoral contribution this study makes to the body of knowledge. The chapter further provides recommendations to stakeholders of the SADC water sector, as these relate to general knowledge production in the SADC water sector, and the contribution research capacity development programmes, such as the WARFSA, could make to knowledge production and policy and practitioner aspects as evident from WARFSA-funded research projects.

The chapter concludes with limitations experienced, and recommendations for future research.

13.2 Results of the study

Empirical analysis provided support for the hypotheses, with results as follows:

13.2.1 Hypothesis 1: The WARFSA programme increased knowledge production.

This study analysed citation data from knowledge produced in the SADC water sector between 1980 and 2016, which provided a study period prior to, during and after the implementation of the WARFSA-programme, which was between 2000 and 2007.

Since the WARFSA programme was but one initiative to support research in the SADC region, it was found that the WARFSA programme had direct and indirect impacts on knowledge production in the SADC region, with most of the direct benefits evident in SADC countries, excluding South Africa. First, and to provide context, results of knowledge production in the SADC water sector as a whole are presented, where the WARFSA programme had an indirect impact, as overall, between 1980 and 2000, SADC countries have been more active in water research than their counterparts on the continent. In addition, in the SADC region, we also need to distinguish between those countries that have consistently been more active between 1980 and 2016 in terms of in-country water research than the SADC average, such as Botswana, Swaziland, Namibia and Lesotho. There have also been SADC countries, such as Zambia, Madagascar and Angola, who have consistently been less active than the SADC average in terms of in-country water research in the period 1980–2016. In some SADC countries, such as Botswana, Swaziland, Zimbabwe (significantly), Namibia (also significantly), Mozambique, Tanzania, Malawi, Zambia, Madagascar, the Democratic Republic of Congo (DRC) and Angola, the Activity Index (AI) score has increased, reflecting an increased focus on water research publications since 2000 as opposed to other research fields. There are also SADC countries, such as Lesotho, South Africa (both marginally), Seychelles and Mauritius, where the AI score has mostly decreased since 2000, indicating a significant decrease in the activity of water research when compared to other research fields.

During the study period, four out of five water research publications in the SADC region emanated from researchers affiliated with South African institutions. When one excludes South African publications from the total SADC water research scenario (referred to as SADC-ExSA countries), the significant increase in the share of SADC-ExSA countries is evident as the share of water research publications increased from 10% in the period 1980–1999 to 26% in the period 2000–2016. It is evident that the most significant increases came from Tanzania, Zimbabwe, Botswana and Malawi. Other SADC countries, which have increased their share of SADC water research, are Namibia, Mozambique, DRC, Zambia and Swaziland. On the other hand, there are SADC countries where the contribution to SADC water research has declined. These are South Africa (albeit marginally), Lesotho and Mauritius. This increase in publications from SADC-ExSA countries correlates with the start of the WARFSA programme in the early 2000s. The results do not show the differences in resources each of the countries has, and for this reason, the normalised per capita output of water research for the different SADC countries was calculated. Here it becomes evident that before 2000, South Africa and Mauritius produced the highest number of per capita water research publications, followed by Botswana, Mauritius and Namibia. Since the turn of the century, Botswana, Seychelles, South Africa, Namibia and Zimbabwe have increased their per capita water research publications.

There is further evidence that the WARFSA-programme had a direct impact on knowledge production.

From the analysis, empirical evidence exists that research publications emanating from the WARFSA programme greatly contributed towards research publications in the SADC region, specifically in SADC-ExSA countries, and between 2000 and 2008, which is closely linked to the implementation period of the WARFSA programme. Many researchers who are affiliated with universities and research institutions in SADC-ExSA countries, and who have published more than 10 articles, can be associated with at least one publication emanating from WARFSA programme. On the other hand, only a handful of researchers from South African institutions can be associated with WARFSA-related research publications. Moreover, several SADC-ExSA countries have increased their water research output since the turn of the century, such as Botswana, Lesotho, Madagascar, Malawi, Mozambique, Namibia, Swaziland, Tanzania, Zambia and Zimbabwe, with countries such as Malawi, Tanzania and Zimbabwe significantly increasing their water research output. Especially the latter countries were substantial recipients of WARFSA-funded projects.

13.2.2 Hypothesis 2: The WARFSA programme increased the visibility of SADC publications

Evidence exists that the WARFSA programme contributed significantly towards the scientific knowledge in the SADC water sector during its implementation between 2000 and 2007, and specifically in research institutions in the SADC-ExSA countries, with quite a number of articles, conference proceedings and post-graduate degrees resulting from the programme. There were, however, few book chapters and policy documents. During the implementation period of the WARFSA programme, co-authorship of articles increased, not only in the SADC region as a whole, but further evident in the articles emanating from the WARFSA programme, along with the citation of articles. Research articles published from the WARFSA programme were (and still are to this day), being cited by the research community, not only regionally, but further afield beyond Africa and globally, indicating their relevance, even after the conclusion of the programme approximately 10 years ago. One however has to acknowledge that even though these articles are widely cited, their visibility is well below the South African, other SADC countries and global average.

13.2.3 Hypothesis 3: The WARFSA programme increased the use of research by policymakers

The qualitative interviews produced evidence of the existence of two communities in the SADC water sector, with on the one hand, the research community and, on the other hand, policymakers and practitioners. Researchers felt that government structures, especially at a regional level, hindered them from having access to ministers and policymakers, with a perspective (from the scientists) that policymakers are ill-equipped to understand the technical intricacies of their work. There is further a suggestion that few scientists embarked upon a deliberate and proactive dissemination strategy (claiming a lack of funding), and that the initial purpose of the WARFSA was purely to fund research and not to target policy uptake necessarily. Evidence exists that mechanisms were put in place by the WARFSA board, especially in the selection phase of projects, to encourage policy uptake of projects, and especially in the second phase of the WARFSA. However, policy outcomes did not necessarily materialise, due to a lack of a deliberate action and strategy from the programme implementation perspective to disseminate research to policymakers and practitioners. In addition, there is a perspective from novice researchers that their research was being undermined and that this limited their ability to influence policies.

Evident exists that some policy and practitioner uptake of research findings did take place, and this often resulted through the personal involvement of the researchers in their areas of influence, and it often resulted over a long period and spanned several research projects. The role of personal networks in mediating results and maximising uptake was repeatedly stated. Apart from involving policymakers and practitioners in the early stages of their research projects, evidence was found of respondents who involved practitioners and policymakers in various capacities *during* their research projects. In addition, the role of (organisational) intermediaries (such as WRC) in optimising impact through publications and lobbying was also clearly stated, and especially the very important role of the annual WaterNet/WARFSA/GWP SA symposium, to create a platform for WARFSA researchers and policymakers to connect and share research findings. Other organisational mechanisms were also available to report and attribute research uptake with corroborating evidence, such as the UK-REF.

In conclusion, it is clear that many of the findings are in line with the broader body of literature and existing theories relating to the policy uptake of research findings. In this study, evidence suggests that two communities exist with researchers on the one hand, and policymakers and practitioners on the other. However, it is clear that the gap might not be significant, given the evidence that some policy interaction did occur, and that some research did translate into practice. Such findings are in line with more recent research in Australia (Newman, Cherney

& Head, 2015), where more than 2 000 policy officials were surveyed, and findings propose that policymakers and academics should focus on bridging instruments. The important role organisational intermediaries such as the WRC are regarded to play in publishing and lobbying policy uptake of research findings is evident. Moreover, even though the annual WaterNet/WARFSA/GWP SA symposium is not an organisation in its own, it is regarded as an important platform in the SADC region for researchers to present their research findings, with the potential to use the opportunity to influence policymakers.

13.3 Relevance and contribution to doctoral studies in the SADC water sector

As indicated in the previous section, various results emanated from this study, all contributing to the body of knowledge. This section highlights the relevance and contribution this study has made to the doctoral body of knowledge.

1. Through a bibliometric analysis of water research publications in the SADC water sector, the study provide a comprehensive analysis of knowledge produced in the sector between 1980 to 2016.
2. With extensive studies previously undertaken on the knowledge production in the South African water sector, the knowledge production from SADC-Excl.SA countries are presented in this study.
3. The knowledge produced by research projects funded through Phase I and II of the WARFSA programme was analysed for the first time.
4. Moreover, a qualitative assessment of WARFSA-funded projects provide insight into policy- and practitioner uptake emanating from the WARFSA-funded research, which was not done previously.

13.4 Limitations of the study

This study project experienced the following limitations as highlighted throughout the document.

1. As indicated in the methodology chapter of this study, water research is a multidisciplinary research field. When extracting bibliometric datasets for this study, publications only categorised as ‘WATER RESOURCES’ in the Web of Science citation database were used.
2. Bibliometric data analysis of publications in this study reflect only publications captured in the Web of Science citation database, recognising limitations of publications which might have been published and not captured in the citation databases.

3. Chapter 10 of this study only focuses on the knowledge production of the WARFSA programme. It is recognised that various other research programmes and organisations exist, which support water research in the SADC region, however their specific contributions were not analysed. Some of the programmes include the WaterNet Masters Programme in IWRM, the AU/NEPAD Southern African network of Water Centres of Excellence (AU/NEPAD SANWATCE), the Applied Centre for Climate & Earth Systems Sciences (ACCESS), Southern African Science Service Centre for Climate Change and Adaptive Land Management (SASSCAL), the International Water Management Institute (IWMI), and in South Africa, the Water Research Commission (WRC), as presented in chapter 6 of this study.
4. The HERG Payback Framework provides a framework to evaluate the potential benefit of research in four impact dimensions, with impact dimensions being science-, policy-, economic- and social impacts. In analysing the impact of the WARFSA programme, this study was limited to the assessment of the first two impact dimensions, being science impact (knowledge produced) and the policy-and practitioner aspects as evident from WARFSA-funded research projects.

13.5 Recommendations

The results from this study leads to the following recommendations:

1. The HERG Payback Framework provide a broad framework for the analysis of the impact of research, and do provide four research impact dimensions. However, it was observed during this project that there is potential to adapt the HERG Payback Framework, given the ecological nature of water research. In addition, the HERG Payback Framework was originally developed for the health sector. It is thus recommended that the HERG Payback Framework be adapted for research projects which include ecological aspects. A theoretical framework is proposed as the Payback-Eco Framework.
2. Should further phases of the WARFSA programme be undertaken, implementers of the programme could consider various aspects of the Payback-Eco Framework, such as the various impact dimensions (science-, policy-, economic- social- and ecological impacts) and the implementation of IOM Tools.
3. One of the major challenges in research evaluation, it to attribute research impact to specific research projects and programmes. In order to attribute the benefits of scientific research to policy-makers and practitioners, survey methods such as survey questionnaires and in-depth interviews with researchers should be undertaken throughout the life-span of research projects. This implies that the potential impact of a research project should be considered starting from the inception of a project, while research is

undertaken, and *post* project. The same methodology would apply when determining the benefits of research to the economy, society and the ecological environment.

4. It is recommended that the task to evaluate the impact of research be institutionalised (as proposed by Bell, Shaw & Boaz [2011]), and undertaken separate from the scientific research team.
5. It is argued that there would be an additional burden on researchers to evaluate the utilisation and uptake of research. Burdens include specific research- utilisation and evaluation knowledge and skills, which could place additional pressure on the research team to perform such impact evaluations. Moreover, additional costs could further burden the research project (unless it has been budgeted for), thus it is recommend that such an evaluation unit be established outside the research projects in the institutions.

13.6 Future research

Based on the findings, limitations and recommendations from this study project, future research could consider the following:

1. As this study focussed on the knowledge production and policy dimension resulting from WARFSA-funded research projects, further research could be conducted to evaluate the economic-, ecological- and social benefits derived from the WARFSA programme itself.
2. There has been notable developments regarding altmetrics with, for example, the integration of the altmetric platform Plum Analytics (www.plumanalytics) into Elsevier in 2017. Such integration provide a broader view on the use of research outputs on media platforms beyond Citation Index databases. Given that such developments are fairly recent, altmetric scores were excluded from this study, and could provide useful information in refining the bibliometric analysis of water research in the SADC region.

13.7 Conclusions

As evident from this study, various universities and research institutions provide opportunities for water research in the SADC region which has resulted in the publication of water research. This study highlighted the domination of South African universities and research institutions in this field with four out of five publications between 1980 and 2016 published by South African institutions. Water research in the SADC region, such as Zimbabwe, Tanzania, Malawi and Botswana have increased since the turn of the century, with signs that many countries increase their in-country effort on water research. Notable support from the Netherlands, through researchers at the Delft–UT, have contributed towards building research capacity in SADC-

ExSA countries, as regional programmes such as the WaterNet Masters Programme in IWRM, and annual WaterNet/WARFSA/GWP SA symposium gained momentum. These days, the symposium is regarded as the largest annual gathering of water professionals in the region, with many alumni from the WaterNet Master Programme and WARFSA employed in the SADC region today.

With limited funding available for SADC countries excluding South Africa, water research programmes such as the WARFSA have demonstrated that they could contribute significantly towards knowledge production, but are however heavily dependent on donor funding from abroad. As further evident, the time lag since the WARFSA programme concluded in 2006, and when the bibliometric aspects of this study were conducted in 2015/2016, proved of benefit but also as a constraint in certain aspects. The time lag proved beneficial in assessing the scientific impacts of WARFSA-funded research outputs as the citing of articles often occur only after a few years. On the other hand, the time lag proved problematic for assessing the policy/practitioner uptake from the WARFSA programme, as limited research project documentation was available with only a few of project PIs contactable. The study did however provide valuable insight into the relationship between researchers and the policy-makers/practitioners, and methods researcher employed to bridge an apparent gap between the research community and policy-makers/practitioners.

Where research impact evaluations are undertaken *ex post*, and especially if it is undertaken after a number of years as in the case of this study, meta-data on the different research projects might be limited. Moreover, project PIs and associated researchers might have difficulty attributing research impact to the specific research after such a long time. Although outcomes might have materialised since the conclusion of the WARFSA-programme in the mid-2000s, a structured methodology was not followed to track outputs, which leads to a situation where it becomes extremely difficult to attribute research impact of the WARFSA programme. The study did however succeed in providing some benchmark.

Future research could further develop the theoretical framework used in this study and address some of the issues raised above, to support the evaluating of research projects with an ecological dimension.

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Annexure A

Research Councils and Centres (excluding Universities and Poytechnics) in the SADC region

Country	Research Councils and Centres (excluding Universities)
Angola	National Scientific Research Centre Agronomic Research Institute Institute for Veterinary Research in Secretaria de Estado do Café: Instituto do Café de Angola (INCA) Institute du Dévelopment Forestie Angola Medical Research Institute Angolan Directorate of Geological and Mining Services Instituto Angolano de Normalização e Qualidade Programa Nacional de Mandioca (PNM)
Botswana	Botswana Technology Centre (BOTEC) The Rural Industries Promotions Company of Botswana Botswana Institute for Development Policy Analysis (BIDPA) Botswana Vaccine Institute (BVI) Veld Products Research & Development (VPR&D) Private sector research institution. Thusano Lefatsheng Private sector research institution.
Democratic Republic of Congo	National Institute For Agricultural Study And Research (INERA) Nuclear Research Centre Geographic Institute of DRC The Centre For Geological And Mineral Research Institut National de Recherche Biomedicale The Institute of Nature Conservation
Lesotho	National Centre for Innovation and Research (NCIR) Ministry of Agriculture (MA) Regional Innovation Centers (RIC)
Madagascar	National Centre of Applied Research in Rural Development; Pasteur Institute of Madagascar (IPM); Bibikely Biodiversity Institute
Malawi	Government based research institutions: Central Veterinary Laboratory Central Water Laboratory Community Health Sciences Unit Department of Agricultural Research Services (DARS) Fisheries Research Unit Forestry Research Institute of Malawi (FRIM) Geological Survey Department Health Sciences Research Unit (HSRU) Meteorological Department National Aquaculture Centre Wildlife Research Unit in the Department of Parks and Wildlife Statutory research Institutes: Malawi Industrial Research and Technology Development Centre (MIRTDC) National Herbarium and Botanic Gardens of Malawi (NHBG)

Country	Research Councils and Centres (excluding Universities)
	Private research Institutes: Agricultural Research and Extension Trust (ARET) Tea Research Foundation of Central Africa (TRF) Illovo Sugar (Malawi) Ltd International research Institutes: WorldFish Centre International Centre for Research in Agroforestry (ICRAF) International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) The International Institute of Tropical Agriculture (IITA)
Mauritius	Mauritius Sugar Industry Research Institute (MSIRI) Mauritius Institute of Health (MIH) Mauritius Institute of Education (MIE) Mahatma Gandhi Institute (MGI)
Mozambique	Ministry of Transport and Communication Instituto Nacional de Hidrografia e Navegação (INAHINA) Instituto Nacional de Meteorologia (INAM) Ministry of Health Instituto Nacional de Saú de (INS) Centro de Investigação de Saúde da Manhiça (CISM) Centro Regional de Desenvolvimento Sanitário (CRDS) Ministry of Agriculture (MINAG) Instituto de Investigação Agrária- IIAM (experimentação florestal,investigação veterinária,produção animal e investigação agronómica) Cenacarta-Centro Nacional de Cartografia eTeledeteção Instituto de Produção Animal (IPA) Instituto Nacional de Investigação Agronómica (INIA) Instituto Nacional de Investigação Veterinária (INIVE) Centro de Experimentação Florestal (CEF) Ministry of Fisheries Instituto de Desenvolvimento de Pesca de Pequena Escala (IDPPE) Instituto de Investigação Pesqueira (IIP) Ministry of Public Works & Housing Laboratório de Engenharia de Moçambique (LEM) Council of Ministers Instituto Nacional de Estatística (INE) Ministry of Education and Culture Instituto de Nacional de Desenvolvimento de Educação (INDE) Instituto de Investigação Sócio-Cultural (IISC-ARPAC) Universidade Eduardo Mondlane (UEM) Universidade Pedagógica (UP) Instituto Superior de Relações Internacionais (ISRI)

Country	Research Councils and Centres (excluding Universities)
	Ministry of Industry and Commerce Instituto Nacional de Normalização e Qualidade (INNOQ) Ministry of Justice Centro de Formação Jurídica e Judicial (CFJJ) Ministry of Culture Instituto de Investigação Sociológica e Cultural (IISC/ARPAC) The International Institute of Tropical Agriculture (IITA) International African-based research for development organization.
Namibia	Desertification Programs by the Desert Research Foundation of Namibia (DRFN) Sam Njoma Marine & Coastal Research Centre Namibian Institute of Mining and Technology Central Veterinary Laboratory Geological Survey of Namibia Forensic Laboratory National Forestry Research Centre National Botanical Research Institute National Museums and Archives Ministry of Fisheries and Marine Resources (MFMR)
Seychelles	The Seychelles Centre for Marine Research & Technology Marine Parks Authority (SCMRT-MPA) ("The Seychelles Centre for Marine Research & Technology Marine Parks Authority (SCMRT-MPA)," n.d.) Seychelles National Parks Authority ("Seychelles National Parks Authority - Research," n.d.)
South Africa	Africa Institute of South Africa (AISA) Agricultural Research Council Council for Geosciences (CGS) Council for Scientific & Industrial Research (CSIR) Human Sciences Research Council (HSRC) Medical Research Council (MRC) Mintek National Research Foundation (NRF) the national R&D body, who also manage the following national research facilities: South African Astronomical Observatory (SAAO) Hartebeesthoek Radio Astronomy Observatory (HartRAO) Hermanus Magnetic Observatory (HMO) South African Institute for Aquatic Biodiversity (SAIAB) South African Environmental Observation Network (SAEON) National Zoological Gardens (NZG) iThemba Laboratory for Accelerator-Based Sciences (iThemba LABS) South African Bureau of Standards (SABS) Government departments National Health Laboratory Services (NHLS) Biodiversity Institute (SANBI),

Country	Research Councils and Centres (excluding Universities)
	South African Weather Services (SWAS) Marine and Coastal Management (MCM) South African Nuclear Energy Corporation (SANEC) State museums (e.g. the Northern Flagship Institution, National Museum, Natal Museum and Iziko Museums of Cape Town).
Swaziland	No other research institute apart from the University of Swaziland
United Republic of Tanzania	Tanzania Industrial Research and Development Organisation (TIRDO) Muhimbili Medical College Ocean Road Cancer Institute (ORCI) Government agricultural research institutes: Ministry of Agriculture and Food Security (MAFS) Ministry of Natural Resources and Tourism Ministry of Health National Institute of Medical Research Tanzania Food and Nutrition Centre Non-Profit Agricultural research institutes: Tanzania Coffee Research Institute (TACRI) Tea Research Institute of Tanzania (TRIR) Tanzania Commission for Science and Technology (COSTECH) associated research institutes: *Industrial Research* Tanzania Industrial Research and Development Organisation (TIRDO) Tanzania Engineering Manufacturing and Design Organisation (TEMDO) Tanzania Bureau of Standards (TBS) Building Research Unit (BRU) National Construction Council (NCC) Tanzania Industrial Studies and Consulting Organisation (TISCO) Tanzania Automotive Technology Centre (TATC) Institute of Production Innovation of the University of Dar es Salaam (IPI) *Health and Medical Research* National Institute for Medical Research (NIMR) *Food and Agricultural Research* Centre for Agriculture Mechanisation and Rural Technology (CAMARTEC) Tropical Pesticides and Research Institute (TPRI) Tanzania Food and Nutrition Centre (TFNC) Tanzania Fisheries Research Institute (TAFIRI) *Natural Resources Research* Tanzania Forestry Research Institute (TAFORI) Tanzania Wildlife Research Institute (TAWIRI) *Energy Research* Tanzania National Radiation Commission (NRC)

Country	Research Councils and Centres (excluding Universities)
	Social Sciences Research National Social Welfare and Training Institute *Environmental Research* National Environmental Management Council International Research Institutes: International Institute of Tropical Agriculture (IITA) International Council for Research in Agroforestry (ICRAF).
Zambia	National Council for Scientific Research of Zambia (NCSR) Zambian Agricultural Research Institute (ZARI) which is part of the Ministry of Agriculture and Livestock ("Zambia Agriculture Research Institute," n.d.) Public research Institutions: Tropical Diseases Research Centre National Institute for Scientific and Industrial Research (NISIR) The Soils and Crops Research Branch (SCRB) Central Veterinary Research Institute (CVRI) & Central Fisheries Research Institute (CFRI) Forestry Research Branch (FRB) Private Research Institutes Macha Malaria Research Institute Centre for Policy Research and Analysis (CePRA) ZamSeed, Maize Research Institute & Dunavant Trusts Golden Valley Agricultural Research Trust (GART) The Cotton Development and Livestock Development Trusts
Zimbabwe	Government: *Ministry of Lands, Agriculture and Water Development* Department of Research and Specialist Services (DRSS) Veterinary Research Laboratory (VRL) Tsetse and Trypanosomiasis Control Branch (TTCB) Institute of Agricultural Engineering (IAE) *Ministry of Natural Resources and Tourism* Aquatic Ecology and Fisheries Branch (AEFB) Forestry Commission: Forest Research Centre (FRC) The Scientific and Industrial Research and Development Centre (SIRDC) *Ministry of Health* The Blair Research Institute comprises the Blair Research Laboratories in Harare and the De Beers Research Laboratory in Chiredzi *Research Council of Zimbabwe*

Country	Research Councils and Centres (excluding Universities)
	The Medical Research Council of Zimbabwe(MRCZ) Non-Profit: Pig Industry Board (PIB) Tobacco Research Board (TRB) Agricultural Research Trust (ART) Seed Co-op Company of Zimbabwe Ltd - Rattray Arnold Research Station (RARS) Zimbabwe Sugar Association (ZSA) Private The Medical and Actuarial Research Foundation (MARF) World Health Organization (WHO) NGO's The Biomedical Research and Training based in Harare The Training and Research Support Centre (TARSC) Equinet, the Network on Equity in Health in Southern Africa

Source (unless otherwise stated): Adopted from Mouton, J. (2008) - *Science & Technology: A Baseline Study on Science and Technology and Higher Education in the SADC Region*.

Annexure B

Journal list: Science Citation Index Expanded - Water Resources

Source:**http://science.thomsonreuters.com/cgi-bin/jrnlst/jlresults.cgi?PC=D&SC=ZR**

Total Journals: 87

1. Advances In Water Resources
2. Agricultural Water Management
3. Aquatic Conservation-Marine and Freshwater Ecosystems
4. Canadian Water Resources Journal
5. Catena
6. China Ocean Engineering
7. Clean-Soil Air Water
8. Desalination
9. Desalination and Water Treatment
10. Ecohydrology
11. Engenharia Sanitaria E Ambiental
12. Environmental Earth Sciences
13. Environmental Fluid Mechanics
14. Environmental Geochemistry and Health
15. Environmental Science-Water Research & Technology
16. Environmental Toxicology
17. Exposure and Health
18. Geomatics Natural Hazards & Risk
19. Ground Water Monitoring and Remediation
20. Groundwater
21. Grundwasser
22. Houille Blanche-Revue Internationale De L Eau
23. Hydrogeology Journal
24. Hydrological Processes
25. Hydrological Sciences Journal-Journal Des Sciences Hydrologiques
26. Hydrologie Und Wasserbewirtschaftung
27. Hydrology and Earth System Sciences
28. Hydrology Research
29. International Journal of Disaster Risk Reduction
30. International Journal of Disaster Risk Science
31. International Journal of Sediment Research
32. International Journal of Water Resources Development
33. Irrigation and Drainage
34. Irrigation Science
35. Journal American Water Works Association
36. Journal of Contaminant Hydrology
37. Journal of Flood Risk Management
38. Journal of Hydraulic Engineering
39. Journal of Hydraulic Research
40. Journal of Hydro-Environment Research
41. Journal of Hydroinformatics
42. Journal of Hydrologic Engineering
43. Journal of Hydrology
44. Journal of Hydrology and Hydromechanics
45. Journal of Irrigation and Drainage Engineering
46. Journal of Pipeline Systems Engineering and Practice
47. Journal of Soil and Water Conservation
48. Journal of The American Water Resources Association
49. Journal of Water and Climate Change
50. Journal of Water Resources Planning and Management
51. Journal of Water Reuse and Desalination
52. Journal of Water Sanitation and Hygiene for Development
53. Journal of Water Supply Research and Technology-Aqua
54. Journal of Waterway Port Coastal and Ocean Engineering
55. Lake and Reservoir Management
56. Membrane Water Treatment
57. Mine Water and The Environment
58. Natural Hazards

59. Natural Hazards and Earth System Sciences
60. Natural Hazards Review
61. Ocean & Coastal Management
62. Physics and Chemistry of The Earth
63. Proceedings of The Institution of Civil Engineers-Maritime Engineering
64. Proceedings of The Institution of Civil Engineers-Water Management
65. River Research and Applications
66. Soil and Water Research
67. Stochastic Environmental Research and Risk Assessment
68. Tecnologia Y Ciencias Del Agua
69. Urban Water Journal
70. Vadose Zone Journal
71. Wasserwirtschaft
72. Water
73. Water Air and Soil Pollution
74. Water Alternatives-An Interdisciplinary Journal On Water Politics and Development
75. Water and Environment Journal
76. Water Environment Research
77. Water International
78. Water Policy
79. Water Quality Research Journal of Canada
80. Water Research
81. Water Resources
82. Water Resources Management
83. Water Resources Research
84. Water SA
85. Water Science and Technology
86. Water Science and Technology-Water Supply
87. Wetlands Ecology and Management

Annexure C

List of WARFSA funded research projects used in this study

ID	WARFSA Phase	Project No.	Title	PI Name	PI Surname	Project Title
1	I	P01	Dr	Moses	Chimbari	Pollution implications of using wastewater for irrigation of pasturelands
2	I	P02	Dr	Anthony	Turton	Water Demand Management (WDM), natural resources reconstruction and adaptive capacity
3	I	P9	Dr	Morris	Chidavaenzi	Rainwater harvesting technology development for rural institutions and village households
4	I	P16	Dr	Sibekile	Mtetwa	Establishment of reference sites for a bio-monitoring water quality assessment network in Zimbabwe
5	I	P18	Dr	Thomson	Sinkala	Control of aquatic weeds in the Lower Kafue River, Zambia
6	I	P19	Dr	Evans	Kaseke	Integrated water and pollution management in the Chivero Basin
7	I	P20	Dr	Washy	R Nyabeze	Analysis of hydrological droughts in Zimbabwe
8	I	P23	Dr	Klaudia	Schachtschneider	Water Demand Management study in Namibian Tourism Facilities
9	I	P32	Dr	Caleb	Muzariri	Microbial enzymes for pollution control in the pulp and paper industry
10	I	P34	Dr	David	Proudfoot	Studies of pathogen decay during storage and composting of human excreta: A prerequisite for promoting Eco-sanitation
11	I	P35	Dr	Keith Japhet	Mbata	Assessment of the effectiveness of the biological control of water hyacinth in the Kafue River
12	I	P40	Dr	Hassani J.	Mjengera (Collaborator: Geodfrey Mkongo)	Defluoridation of drinking water in Tanzania
13	I	P42	Dr	Deric S.	Moono	Multivariate, criteria and objective analysis of irrigation in Namibia using systems analysis and modelling
14	I	P43	Eng.	Kwinisa	Bwanali	Regionalising CCD-Rainfall estimation in Zimbabwe
15		P54a	Dr	M	Chimbari	Pollution implications of disposal of wastewater through irrigating of pasture lands
16	I	P54b	Dr	Jabulani Ray	Gumbo	Development of a protocol for the identification and removal of chlorinated organic compounds in a developing world municipal drinking waters: the case of Zimbabwe

ID	WARFSA Phase	Project No.	Title	PI Name	PI Surname	Project Title
17	I	P57	Dr	Nyasha L	Nyagwambo	Mupfure Basin: Land-use, Groundwater-Surface water interactions
18	I	P58	Dr	Francis T.	Gonese	Broadening access and integrating water management institutions: Water sector reform experiences in Zimbabwe and Malawi
19	I	P62	Dr	Gift	Manase	Addressing gender issues in the water supply and sanitation sector in Zimbabwe
20	I	P63	Dr	Dominic	Mazvimavi	The Application of Satellite data for estimating flow characteristics of ungauged catchments.
21	I	P71	Dr	Emmanuel	Manzungu	Sustaining agriculture and livelihoods in the Odzi sub-catchment
22	I	P76	Dr	Richard	Owen	Groundwater yield in cystalline rocks: Mapping the relationship between yield, fracture pattern, erosion surface and stress field in the Zimbabwe craton
23	I	P83	Dr	Sibekile	Mtetwa	"An interactive approach to development decision making tools for diffuse pollution control in rural areas" ALTERNATIVE TITLE: "Establishment of reference sites for a biomonitoring water quality assessment network in Zimbabwe"
24	I	P91	Dr	Jonathan I	Matondo	Evaluation of the impact of climate change on hydrology and water resources in Swaziland
25	I	P92	Dr	James	Ngana	Integrated water resources management in the Lake Manyara
26	I	P114	Dr	James M	Tembo	Potential of rainwater harvesting in urban Zambia
27	I	P123	Dr	Sue	Walker	Quantifying precipitation use efficiency for maize-bean inter-crop
28	II	P105	Prof.	Abu A. A. K.	Mvungi	Socio-economic aspects of Traditional Irrigation canal system among smallholder farmers in Mwanga District ALTERNATIVE TITLE OF ARTICLE: Management of water for irrigation agriculture in semi-arid areas: Problems and prospects
29	II	P106	Dr	Graciana	Peter	Assessment of the socio-economic impact of water project on women’s development in Swaziland
30	II	P113	Dr	Boniface	Mbilinyi	Assessment of potential and effectiveness of rainwater harvesting for land productivity and water availability

ID	WARFSA Phase	Project No.	Title	PI Name	PI Surname	Project Title
31	II	P116	Dr	David	Love	Urban groundwater chemistry & contamination in the City of Harare
32	II	P118	Dr	Edward	Guzha	A field trial of urine diversion toilets and human excreta use
33	II	P119	Dr	Ignatius	Ncube	Single step-activated carbon production from agro-forestry wastes. Article Title: Activated carbon produced from agro-forestry wastes using single-step steam pyrolysis
34	II	P122	Dr	Kudakwashe E.	Motsi	Rainwater harvesting for sustainable agriculture in communal lands
35	II	P129	Dr		Lughanouka	Impact of water conservation programmes on land use patterns, environmental degradation and occurrence of human and animal diseases
36	II	P130	Prof.	Jamidu	Katima	Fluidized Bed Reactor-Artificial Wetland for treatment of industrial wastewater
37	II	P138	Prof.	Zebedayo	Mvena	Sustainable water use in Ukaguru and Ikowa catchments in Morogoro and Dodoma regions
38	II	P142	Dr	Buyoya	Masola	Development of active biomonitoring protocols for instream toxicity
39	II	P143	Dr	Felix	Ntengwe	Awareness of water sector issues induces a positive impact on cost recovery and willingness to pay in Zambia
40	II	P144	Dr	Faustin	Maganga	Implications of customary laws for implementing Integrated Water resources Management
41	II	P147	Dr	Shadrack	Mwakalila	Sustainable management of water resources using integrated approach
42	II	P148	Dr	Sharon	Pollard	Linking water and livelihoods: the development of an integrated wetland rehabilitation plan in the communal areas of the Sand River catchment as a test case
43	II	P149	Dr	Chimwemwe	Chikusa	Effectiveness of existing institutional support for enhancing community based management of potable water supplies in Malawi. (Focussing on Boreholes)
44	II	P150	Dr	D.	Kafumbata	Water resource management in Southern Malawi: Case of Mwanga, Lisungwi and Mkulumadzi Rivers
45	II	P151	Dr	Ndina	Nashipili	Baseline study on water use and management in communal areas

ID	WARFSA Phase	Project No.	Title	PI Name	PI Surname	Project Title
46	II	P152	Dr	Linda	Mhlanga	Algae-bacterial relationships within cynobacterial blooms and possible health implications
47	II	P156	Dr	Maryam D.	Said	Climatic Aspects of Cholera in Kwazulu Natal. PhD: Maryam Darwesh Said - Epidemic Cholera in Kwazulu-Natal - the role of natural and social environment.
48	II	P158	Dr	Shamiso	Mtisis	Implementing and enforcing water quality laws in urban areas: Harare and Gweru
49	II	P163	Dr	M. S.	Lugaila	Influence of traditional land use practices on water loss and conversation in Lake Victoria basin in Tanzania
50	II	P166	Dr	Emmanuel	Manzungu	Status of governance for the poor in Zimbabwe
51	II	P167	Dr	Michelo	Syakalima	The impact of heavy metals and pesticides upon fish species in the Kafue River
52	II	P168	Dr	Christos	Sibanda	Assessing traditional RWH Techniques in Botswana, Zambia and Zimbabwe
53	II	P169	Prof.	Hezekiel M.	Mushala	Assessing factors influencing success of water development project
54	II	P170	Dr	Paul K.	Wahome	Prolonging growing period of tomato by regulated irrigation and mulching
55	II	P171	Dr	Clifford	Simango	Prevalence of Clostridium difficile in drinking water
56	II	P173	Mr	Ian Nzali	Banda	Private Sector participation in the Water and Sanitation industry in Zambia “Opportunities & constraints”
57	II	P178	Prof.	Mariam M.	Keregero	Enhancing role of women in water development projects: the case of the Komati downstream development project in Swaziland
58	II	P181	Dr	Lindah	Mhlanga	Cyanobacteria toxin production in a drinking water reservoir with emphasis on ecological and health implication
59	II	P185	Prof.	Henry F.	Mahoo	Modelling of semi-arid based Macro-Catchment Rainwater Harvesting Systems AND ALSO collaborate with BP Mbilinyi: 'GIS-based decision support system for identifying potential sites for rainwater harvesting' AND 'Indigenous knowledge as decision support tool in rainwater harvesting 'Project P113

ID	WARFSA Phase	Project No.	Title	PI Name	PI Surname	Project Title
60	II	P186	Dr	Klaudia	Schachtschneider	Subsurface water and riparian tree interactions in an ephemeral river.
61	II	P189	Dr	Sindy N	Mthimukhulu	Biological assessment of the state of water quality using SASS: A case of the Mbuluzi River, Swaziland
62	II	P191	Prof.	Annemarrie	Avenant Oldewage	Cestode parasites of the African sharptooth catfish, Clarias gariepinus, as bioaccumulation indicators of heavy metal pollution in the Vaal River Catchment area, South Africa
63	II	P196	Dr	Juma Marwa	Wickama	Reducing irrigation water losses on Mt Kilimanjaro slopes - Tanzania
64	II	P199	Dr	Belda Quetina	Mosepele	Aquatic Biodiversity and water quality in the Okavango delta, Botswana
65	II	P204	Dr	Jaap	Arntzen	Towards incorporating wastewater in Water Resource Accounts in Botswana
66	II	P206	Dr	Fungai Sexton	Makoni	Utilisation of wastewater as a potential to improve food security among urban communities in Southern African.
67	II	P221	Dr	Crispen	Phiri	An assessment of the level and effect of pollution along the shoreline of Sanyati Basin (Lake Kariba): An opportunity to develop bio-assessment for detecting pollution
68	II	P200	Dr	PM	Semili	Effects of Physico-chemical factors on phytoplankton production in Lake Victoria, East Africa
69	II	P212	Dr	Emma Teresa	Liwenga	Implications of Rural Migration and expansion of livelihood activities on Water Resources and Wetlandss of the Kilombero Valley, Tanzania
70	II	P215	Dr	Phillip K	Mwanukuzi	Land use Impact on River Flows in Usangu Basin Catchment
71	II	P224	Prof.	Apollinaria	Pereka	Environmental impact on small scale gold mining in lake Victoria Basin
72	II	P229	Ms	Phillipa Rose	Huntsman-Mapila	The distribution and Geochemistry of Arsenic in Groundwater in NW Botswana
73	II	P232	Dr	Theresa	Mkandawire	Plant Extracts to improve Groundwater Quality in Shallow Wells
74	II	P238	Ms	Faith	Mbi (Love)	Environmental Flow requirements for the Lesape River, downstream of Rusape Dam

ID	WARFSA Phase	Project No.	Title	PI Name	PI Surname	Project Title
75	II	P243	Dr	Thokozani	Hove	Studies of cryptosporidial infection in cattle and farm workers on a Harare Municipality farm with treated urban effluent irrigated pastures
76	II	P245	Mr	Alexio	Mbereko	Understanding Conflicts Over Natural Resources Management in Zimbabwe. A case study of Zungwi Vlei (A Small scale irrigation scheme)
77	II	P249	Mr	Antony	Mamuse	High-Flouride Groundwater in Gokwe North District (NW Zimbabwe)'; origin, Distribution, Geochemistry and Health Impacts
78	II	P255	Dr.	Sekesai	Mtapuri-Zinyowera	The effect of solar radiation and sand filtration on drinking water contaminated with intestinal protozoan parasites and the epidemiology of these parasitic infections from diverse communities in Zimbabwe

Annexure D

Protocol for case study interview: outline of semi-structured interview schedule

Assessment of policy aspects from the research funded through the Water Research Fund of Southern Africa (WARFSA).

The precise nature of the interview schedule for each specific interview will be determined by the prior desk analysis undertaken on: analysis of the responses made in the survey; archival and documentary reviews; and possibly previous interviews on related topics.

INTRODUCTION

Discuss background to the study. Conform research project with PI. This is based on available records.

Interview date:

Questions:

BACKGROUND

1. **What was your role in the research project?**

   Project PI? Collaborating researcher? Student?

2. **What was the original impetus for your project?** Solely scientific curiosity?

   The need to fill certain gaps in knowledge? Targeting of a particular research problem? In response to certain

3. **How far was your identification of the research topic influenced by:**
   a. *Research you had done before? Funded by whom?*
   b. *The research of others? If so how did you hear about this research*?

4. **Did this work have any impact on the agenda for your subsequent research?**

5. **Outputs from the project? (confirm with available data)**

   Peer reviewed articles, policy guidelines?

POLICY ASPECTS

6. Was there any involvement of practitioners, or even policy-makers, in the **process of project selectio**n?

7. Were any practitioners involved in **assisting with the research**, and if so did it have any **impact on their attitude towards implementing research findings** in general?

8. Apart from publications, what attempt did you make to **disseminate the findings to academic audiences? More widely?** Did you work with funders or stakeholders to do this?

9. Has the research been **cited directly in any guideline or similar document from a professional body or public policymaking body at national or local level**?

10. Has any of **the subsequent research** by yourself or others that built on the project **been cited in any guideline or similar document from a professional body or public policymaking body at national or local level?** Do you think this might happen in future?

11. Do you know how far the research directly influenced the **formulation of any policy**, or the **realisation that a policy was needed**?

12. If the research has **made some policy impact, what are the key reasons for this**? If it has **failed to have a policy impact what are the reasons for this**? What **barriers** were there to the research having an impact/being translated? What **factors facilitated the research having an impact/being translated**?

Any other questions

Thank you very much