Institute for Water Research

ANNUAL REPORT 2022

RHODES UNIVERSITY
Where leaders learn

IWR

IWR: ARUA Water Centre of Excellence Hub

ARUA
African Research
Universities Alliance

ARUA Water CoE

Centre for Environmental Water Quality

Editor
Helen Holleman

Cover photographs
N Huchzermeyer

Design and layout
Bronwyn Tweedie,
Printing Services Unit,
Rhodes University

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Dr Kathleen Smart	Postdoctoral Fellow
Professor Tally Palmer	Professor; Director: IWR
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Dr Nikite Muller	Senior Research Associate
Dr Eric Igbinigie	Senior Research Associate
Dr Patsy Scherman	Senior Research Associate
Dr Andrew Slaughter	Research Associate
Professor Jill Slinger	Visiting Professor

REGISTERED POSTGRADUATE STUDENTS

Mr Andrew Ali	MSc (Water Resource Science)
Ms Mary Chibwe	PhD (Water Resource Science)
Mr Jaco Greeff	MSc (Hydrology)
Mr Anthony Fry	PhD (Water Resource Science)
Ms Sofia Lazar	MSc (Water Resource Science)
Mr Sakikhaya Mabohlo	MSc (Hydrology)
Ms Zintle Mtintsilana	MSc (Water Resource Science)
Ms Nandipha Ngoni	MSc (Water Resource Science)
Ms Anele Ntshangase	MSc (Water Resource Science)
Ms Harriette Okal	PhD (Hydrology)
Mr Miracle Osoh	PhD (Water Resource Science)
Mr Enahoro Owowenu	PhD (Water Resource Science)
Ms Mateboho Ralekhetla	PhD (Water Resource Science)
Ms Phatsimo Ramatsabana	MSc (Hydrology)
Ms Esther Seriki	MSc (Water Resource Science)
Ms Noleen Tavengwa	MSc (Water Resource Science)

Mr Stefan Theron	MSc (Water Resource Science)
Mr Edgar Tumwesigye	PhD (Water Resource Science)
Mr Peter Wasswa	MSc (Hydrology)
Mr Sinethemba Xoxo	PhD (Hydrology)
Mr Kamva Zenani	MSc (Water Resource Science)

2022 GRADUATED STUDENTS

Ms Asanda Chili	MSc
Ms Bawanile Mahlaba	MSc
Ms Pindi Ntloko	PhD

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A lineage of leadership: a story in memory of Brian Allanson

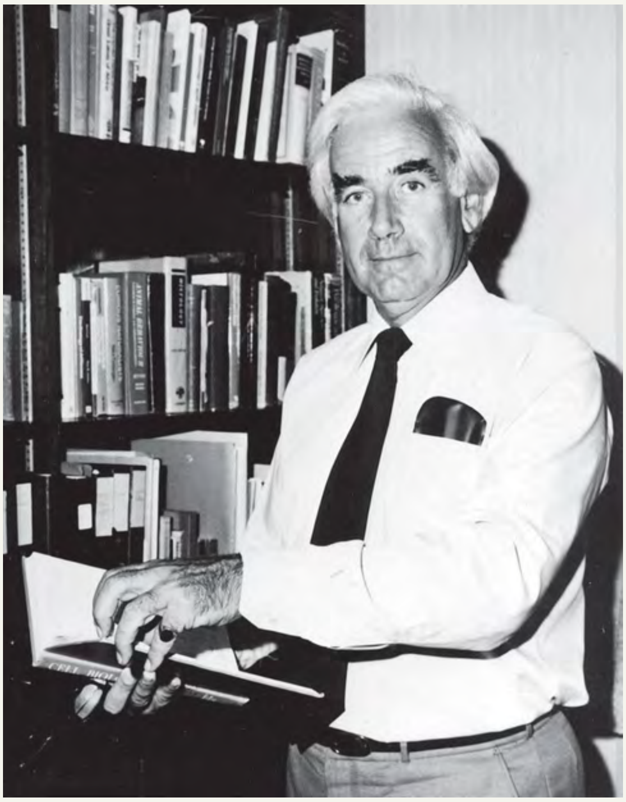
Carolyn (Tally) Palmer
Unilever Centre for Environmental Water Quality, Institute for Water Research, Rhodes University

A recollection written on the banks of a cut-off meander of the Zambezi River

Professor Brian Allanson died in July 2022, and fulsome obituaries have been written chronicling his academic prowess — which was epic. In the past weeks my thoughts have turned in a more personal direction: Brian Allanson — the extraordinary person I was privileged to know. I well remember the day I received a letter from him concerning the South African water law review "*Dear Tally, ... Regards, Brian*". Brian! I had graduated to addressing him in the first person.

I met Brian as a prospective honours student in November 1977, when he was Head of the Zoology Department at Rhodes University. Even now, whenever I walk into the cool foyer of what was then the Zoology building, I remember that day. He was imposing, with the shock of white hair that gave rise to the whispered nick-name of 'Great White God'. I was planning to move from the University of KwaZulu-Natal (Durban) to Rhodes University for two reasons: my fiancé Tony was in the army in King Williams Town, and Durban academic Anthony (Ticky) Forbes, currently the Director of Marine and Estuarine Research (MER) had encouraged me to go to Rhodes — his alma mater. I was interested in estuarine ecology and Ticky said there were no better academics than Brian Allanson and Burke Hill. Brian had a reputation for being less than enthusiastic about women students and I felt both intimidated and defiant. The short interview over, I was accepted and began one of the most challenging years of my life. The Durban-based Department of Biological Science had a groundbreaking, integrated double degree in the biological sciences — but little classical zoology. My first essay for Brian attracted the comment "*poorly understood regurgitated undergraduate nonsense*", the mark — gamma — was a fail. That afternoon I achieved alpha for my first seminar, and zig-zagged through a year of intense learning. Brian was a stickler and accepted only rigorous excellence — and definitively no bare feet!

At the time Brian held positions later to be filled by three professors: Head of Department and Director of



Prof Brian Allanson (1929–2022). Photograph courtesy of DA Forsyth (IWR, Rhodes University)

both the Institute for Freshwater Studies (IFWS), and the Southern Oceans Group. I recall the staggering breadth of deep knowledge he had of all things aquatic: marine, estuarine, and freshwater, from the equator to the poles. It is this driving energy and expansive, generous intellect that has led to what I believe is Brian's greatest legacy — across the world there are leading biologists influenced by him and influencing new generations. I certainly don't know them all — but enough to illustrate what I mean.

In my direct lineage, Brian Allanson recruited Bryan Davies to replace Burke Hill, who moved to Australia. Bryan Davies supervised my MSc at Rhodes and later went on to the University of Cape Town, where Jackie King, Southern African Society for Aquatic Scientists (SASAqS) Gold Medal recipient and winner of the 2019 Stockholm Water Prize, was a doctoral student. Bryan Davies shared with me his admiration of Jackie who undertook her PhD as mother of two young children — an inspiration in my own doctoral studies, also with two young children!

Brian Allanson's IFWS became the Institute for Water Research (IWR) under the charismatic and able leadership of Jay O'Keeffe (my doctoral supervisor), who was first employed by Brian as a post-doctoral researcher! With Jackie King, Jay pioneered environmental flow research methods and applications. Yesterday (13 August 2022), I received a message forwarded to me by Sue O'Keeffe, from one of Jay's colleagues in India: "*Dear Sue, this is the river Ramganga for which both Jay and I worked during 2013–2018… at this location, the river used to be having very little flows, with depth in mere inches… the seeds of the work that he had sown with us, is now bearing fruits… this river is getting back, with authorities passing the Orders for additional water releases into the river… Jay would have been equally delighted like me, with this scene of the river — Ramganga River — and all of us thanks Jay for his contributions…*".

Jackie King has in turn mentored Cate Brown, the 2021 SASAqS Gold Medal recipient, and together they have refined environmental flow assessments into aquatic resources futures modelling and management, with global applications.

The IWR has become a leading water research hub with international influence and is host to the African Research Universities Alliance (ARUA) Water Centre of Excellence. All three of the IWR Directors have been awarded the SASAqS Gold Medal and have been influential leaders: Jay in environmental flows, Denis Hughes (2016 International Hydrology Society Volker medal recipient) in hydrology and hydrological modelling, and Tally Palmer in the South African Water law, environmental water quality, and transdisciplinary engaged catchment research. I hope this inspires the researchers and students in the IWR today to become leaders in their own right, practicing with the commitment to energy and excellence of the founder. The current IWR acting Director, Nelson Odume, and ARUA Water CoE Director, Jane Tanner, are well on their way.

Remaining with freshwater, Clive Howard-Williams left the IFWS for New Zealand to extend southern hemisphere influence, and Paul Skelton, also a Rhodes Department of Zoology and Entomology graduate, SASAqS Gold medal recipient, and leading freshwater fish biologist, oversaw the transition of the JLB Smith Institute of Ichthyology into the South African Institute of Aquatic Biodiversity. As the founding Director, Paul saw the South African Institute for Aquatic Biodiversity (SAIAB) become a national research facility in South Africa, leading strategic aquatic research.

On the marine side, Brian mentored Mike Bruton — a global leader in science education, and inaugural Director of the Two Oceans Environmental Education Trust, and an early Director of the JLB Smith Institute. One of Brian's most eminent successors is Christopher McQuaid — an A-rated marine scientist who became the next Director of the Southern Oceans Group, and supervised William Froneman — Rhodes University Senior Research Medal holder and recent Head of the Department of Zoology and Entomology at Rhodes. William maintained a close relationship with Brian throughout the years of his active retirement.

And so the list goes on — an intricate, expanding net of people working to understand and protect the world's freshwater, estuarine and marine ecosystems, and to engage with the people who love, use, govern and manage them. Outgoing ripples of influence from the towering presence of Brian Allanson.

Brian was not only influential in the academic world, but had influence reaching into the social needs of Brian's long-time hometown — he was a committed Rotarian and influenced many of the current Rotarians in the Grahamstown Club who have recently raised seven million rand to renovate the bathrooms and toilets in eight schools in Makhanda, in a project that includes an action-based education program in careful water-use and hygiene.

My most recent research in river catchments as complex social-ecological systems, forefronts the role of relationships between the multiple elements of each system. An ecology of people and their landscapes. Here I acknowledge the huge legacy of influential relationships given generously by Brian Allanson.

The Ramganga River, flowing in 2022

Reproduced from *African Journal of Aquatic Science* (2022) 47: 421–422 [https://doi.org/10.2989/16085914.2022.2115705] with permission © NISC (Pty) Ltd

IWR DIRECTOR'S REPORT

I begin this report by expressing the Institute's gratitude to Professor Tally Palmer, former Director of the Institute, who retired in 2022. Tally's contribution to the Institute is immeasurable; she has left a strong legacy, fond memories, and deep appreciation on the part of the staff and students of the Institute. Prof. Palmer continues to work with the Institute as an Emeritus Professor. I also thank Emeritus Professor Denis Hughes for his continued contribution to the Hydrology work of the Institute.

In 2022 the Institute undertook its strategic planning exercise. Six strategic objectives were collectively agreed upon by all staff and students: funding; outputs and impact; human capability and wellness; partnerships; technical capacity, and visibility. These objectives will guide the operation of the Institute within the next two to three years.

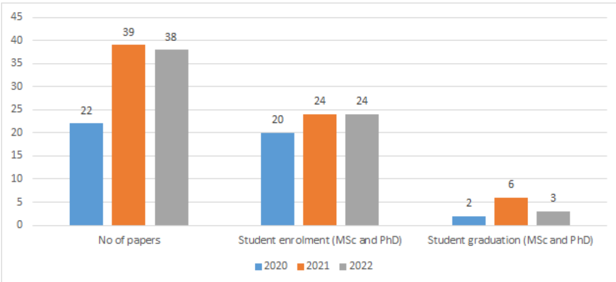
Funding and Projects

As a largely self-funded entity within the University, the Institute's strategic goal is to secure diverse funding sources for salaries, student bursaries, running costs, infrastructure and equipment. The Institute has a total of seventeen externally funded projects (seven local, and ten international projects). Our primary local funding sources remain the Water Research Commission (WRC) and the National Research Foundation (NRF). We are grateful to the WRC and NRF for their continued support of the work of the Institute. Over the years, the IWR has managed to secure increasing amounts of diverse international funding, including the UK Research and Innovation (UKRI), European Education and Culture Executive Agency (EACEA), European and Developing Countries Clinical Trials Partnership (EDCTP), Coventry University, Swedish Research Council, University of Bayreuth, GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit), among others. The project section details the on-going research projects within the IWR and sources of funding.

In 2022, a number of our internationally funded projects come to an end. Notable among them was the climate change and zoonoses project funded by the GIZ. The Capacity Development grant for the ARUA Water CoE funded by the UKRI has also come to an end. The large collaborative project funded by the UKRI within the ARUA Water CoE will come to an end in December 2023. The IWR will continue to work with both local and international partners to produce collaborative research proposals in the coming years.

Outputs and impact

The IWR emphasises high quality, impactful outputs: highly skilled and competent students, community engaged services, high quality publications, and vibrant research programmes. The figure below shows the number of peer-reviewed published papers, student enrolment and student graduation within the IWR over a three-year period. Productivity within the IWR has remained fairly consistent, except in 2020 during Covid, when the number of papers dipped slightly. The increasing number of published papers in prestigious local and international journals with high impact factors is noteworthy.



IWR outputs over a three-year period (2020 – 2022)

Three students graduated and obtained their degrees in 2022. We congratulate Dr Pindiwe Ntloko, Sinethemba Xoxo (MSc) and Asanda Chili (MSc) who obtained their degrees in Water Resource Science, Hydrology and Water Resource Science, respectively. Ms Asanda Chili obtained her degree with distinction, a well-deserved accolade for an excellent piece of research. We wish all our graduates well in their future endeavours. I thank the supervisors and co-supervisors for the mentorship and guidance given to all our students. During the October 2022 graduation, we also celebrated students who had graduated in previous years, but were unable to participate in physical graduation ceremonies due to COVID-19 restrictions. In this regard, we congratulate Dr Akamagwuna and Dr Gwapedza.

Prof. Nelson Odume and Dr Pindiwe Ntloko during the April (2022) graduation.

The IWR staff and students have been very active at local and international conferences, making a total or 17 presentation in 2022. Dr Jane Tanner gave the keynote presentation on the need to integrate society within hydrology, socio-hydrology, at the inaugural South African Hydrology Society (SAHS) conference held in Johannesburg from 10–12 October 2022. Prof. Odume and Dr Akamagwuna presented papers at the 2022 Society for Freshwater Science (SFS) conference held in Grand Rapids, Michigan, USA from May 14–20, 2022. As the Chair of the African Chapter of SFS, Prof. Odume led discussions at this conference on how to strengthen African freshwater science through capacity strengthening and access to global partnerships and initiatives. The SFS has been working closely with SFS Africa Chapter in this regard.

The IWR continues to support students to attend and present at conferences. A total of 10 students from the IWR attended and presented at various conferences. Mr Andrew Ali attended and presented a paper at the 59th Southern African Society of Aquatic Scientists Congress held at the University of the Free State from 26–30 June 2022. Ms Mary Chibwe and Dr Chika Nnadozie presented papers at the World Antimicrobial Awareness Symposium.

From left to right: Dr Jane Tanner, Dr Sukhmani Mantel, Dr David Gwapeza, Ms Asanda Chili, Mr Sinethemba Xoxo, Dr Frank Akamagwuna and Prof. Nelson Odume, at the October 2022 graduation.

Mr Sinethemba Xoxo, Dr David Gwapeza, Mr Sakikhaya Mabohlo and Ms Harriett Okal attended and presented papers at the inaugural conference of the South African Hydrology Society (SAHS). Congratulations to Esihle Gotye who won the best poster award, and Gyaviira Ssewankambo who won the best oral presentation at the SAH conference. Mr Peter Wasswa also presented a paper at the 2nd IGAD Water Dialogue forum held in Entebbe, Uganda from 15–27 January 2022.

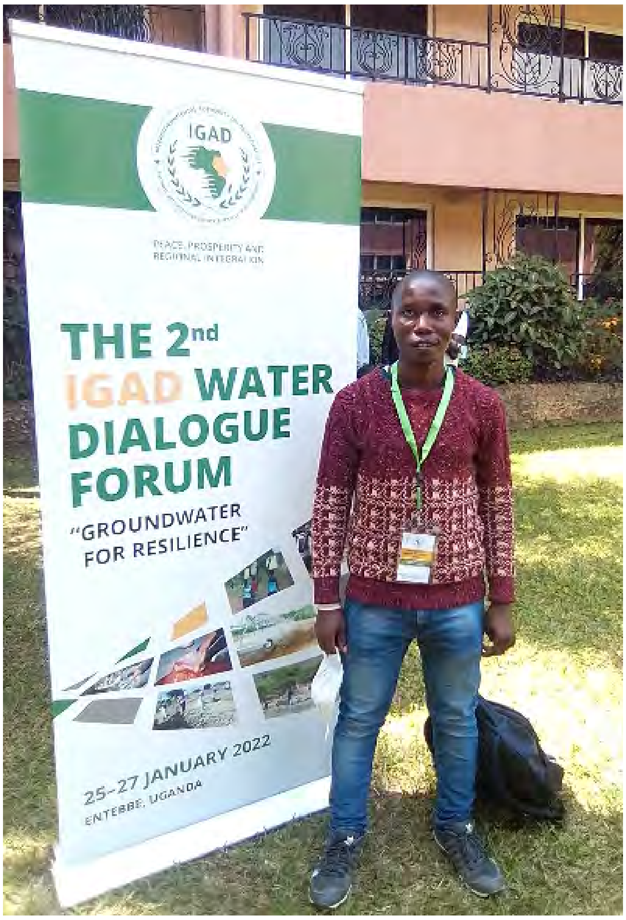
Andrew Ali at the 59th SASAqS 2022 Conference

Human capability and wellness

Human capability and wellness are critical for the functioning of the Institute. The IWR aims to develop emerging leaders, create an enabling environment for growth and capability strengthening, while supporting the wellness of staff and students. One of the major leadership-related decisions made in 2022 was the appointment of Research Group Leaders within the IWR. The Group Leaders ensure that these areas of research are developed, and deepened within the IWR. Dr Jane Tanner who took over the Directorship of the ARUA Water CoE upon Prof. Tally Palmer's retirement, continues to provide leadership for the Hydrology Group. Dr Chika Nnadozie is the Leader for Environmental Water Quality and Ecology. She takes over the leadership of Centre for Environmental Water Quality (CEWQ), while Dr Bukho Gusha leads the Landscape Ecology and Governance Group. Dr Sukhmani Mantel will be leading the institute effort in Science Communication, and Dr Weaver has indicated interest in heading the Water Governance team. Each of the groups will be supported by the IWR Director, ensuring that over the next two to three years, the new groups, particularly Landscape Ecology and Governance as well as Science Communication, become established and attractive to researchers and students who would like to come to the IWR.

The IWR supports co-learning and development opportunities for its staff and students. In this

Dr Chika Nnadozie and Mary Chibwe at the World Antimicrobial Awareness Symposium held at Stellenbosch University, from 21–22 November, 2022.



Mr Peter Wasswa at the 2nd IGAD Water Dialogue Forum.

regard, in 2022 the Institute invested in several learning opportunities. We have a cohort of students who are also actively looking for self-development opportunities within and outside the IWR. Ms Mary Chibwe was supported to attend a course on Molecular Diagnostics to monitor and combat antimicrobial resistance (October to November, 2022). Andrew Ali was selected as one of the 1000 global talents to participate in the Unleash India Global Innovation Lab in Karnataka, India, from 3–11 December 2022. **Unleash** is a worldwide initiative that connects youth to help achieve the SDGs by sharing ideas, building networks, and devising innovative solutions. Participants work together in small teams to learn to frame problems, create new ideas, develop early-stage prototypes, and test those prototypes with potential users. We congratulate Mr Ali on this achievement.

Enahoro Owewenu was selected as a SANO exchange and intern for the Sustainability Programme. The programme is funded by the Norwegian Retailers' Environment Fund and is jointly operated by the Norwegian University of Science and Technology and Sustainable Seas Trust in South Africa. Participants are to work in teams across academic, social, geographic, cultural, and legislative boundaries to combat plastic waste and prevent marine pollution. In the same vein, Mr Peter Wasswa was on a short exchange visit at the Stichting Deltares, in Delft, Netherlands. During his stay in the Netherlands, Peter held the position of Groundwater Researcher (intern) and participated in the Africa Climate Mobility Initiative project. This visit contributes directly to Peter's work at Rhodes University. Mr Edgar Tumwesigye was equally supported to attend the sample preparation and training workshop on analysis of plastic-related pollutant organised by the African Marine Waste Network, Sustainable Sea Trust (SST). The Society for Freshwater Science (SFS) organised a set of training workshops for emerging scientists on the continent, and several of the IWR students took advantage of these opportunities.

Dr Frank Akamagwuna was awarded the Emerge Fellowship of the SFS for 2022. Harriett Okal participated in a doctoral mentorship programme at ETH Zurich. Whilst at Zurich, Harriett worked on Objectives 3 and 4 of her PhD research at Rhodes, in addition to attending seminars on watershed modelling, river basin erosion, nature-based solutions and blue-green infrastructure. Mr Sinethemba Xoxo and Dr David Gwapeza were invited to participate in the Companion Modelling workshop held in Montpellier from 16–20 May 2022. During the workshop they received training on agent-based modelling, which forms part of Mr Xoxo's PhD work at the Institute and Dr Gwapeza's WRC-funded project.

Going forward, the IWR will continue to support learning opportunities and encourage both staff and students to take advantage of such opportunities.

Andrew Ali (1st from left) and his team during the Unleash Global Innovation lab in India.

Enahoro Owewenu at the SANO exchange and interns for Sustainability Programme

Left to right: Dr Darcy Molnar, Ms Harriette Okal, and Prof. Dr Peter Molnar at ETH Zürich, Switzerland

Participants at the Companion workshop in Montpellier.

Partnerships

The IWR fosters partnerships based on strong, transparent and rich relationships with diverse local, national and international institutions and partners. Such partnerships facilitate mutually beneficial opportunities for collaborations and exchange of knowledge, skills and experience. The cover page of our Annual Report this year reflects the extent of partnerships fostered within the IWR. The IWR is the hub of the ARUA Water CoE, and the African Water Resources Mobility Network (AWaRMN). I thank Dr Jane Tanner, Dr Chika Nnadozie, Dr Sukhmani Mantel and Mrs Margaret Wolff who continue to work to maintain these partnerships.

Beyond these, the IWR is also the secretariat for the Africa Chapter of the Society for Freshwater Science (SFS) or which Prof. Odume is the Chairperson. Through Prof. Odume, the IWR is also part of the Africa Multiple Cluster of Excellence, comprising the Rhodes University African Studies Centre. These partnerships open up extensive collaboration between the IWR within the African continent and globally. The project section of this Annual Report reflects the partnership-collaborations that the IWR has fostered over the past few years.

in addition to the current ARUA effort of setting up clusters of excellence between ARUA universities and the Guild, the IWR is in partnership discussion with a number of Centres, Institutes and Universities within Africa and elsewhere with the intention of setting up MOU to facilitate joint research, student and staff exchanges, strengthen research leadership and capability as well as exchange of facilities, and skills.

Going forward, the IWR intends to deepen its collaborative effort within the University. We already have some of these in place, but we would like to further deepen collaboration with Zoology and Entomology, the Centre for Biological Control, the Geography Department, Environmental Science, the Environmental Learning Research Centre (ELRC), the South African Institute of Aquatic Biodiversity (SAIAB), the Institute of Social and Economic Research (ISER), the Albany Museum, the Department of Chemistry, Microbiology and Biotechnology, among others. At this juncture, I wish to express my sincere gratitude to SAIAB, and the Department of Chemistry and Microbiology and Biotechnology who have generously granted our students access to their facilities.

Technical capacity

The IWR recognises the importance of strengthening technical capacity and mentorship. In 2022, our efforts were mainly directed towards our internship programme. The IWR hosted three interns, one of whom, Ms Aphiwe Magwala, was funded by the Groen Sebenza programme implemented by WESSA, and the other two interns, M. Siyabonga Mazibuko and Ms Zuziwe Maqqwayi, were funded by the Water Research Commission. While at the IWR, these interns were exposed to a variety of projects and have acquired both technical and people-management skills. Ms Magwala is now taking up an opportunity in Kwazulu-Natal and Mr Mazibuko is now a registered Honours student in the Department of Microbiology. I thank Dr Chika Nnadozie, Ms Khaya Mgaba and Dr Frank Akamagwuna who provided excellent mentorship for our interns during their stay in the IWR.

Visibility

The IWR seeks to increase its visibility across the University and beyond as an interdisciplinary institute that fosters sustainable impact and innovation locally and globally. Our focus this year has been on fostering new partnerships, increasing our social media presence via Twitter, and updating and maintaining our website. Thanks go to the IWR media team, and Mr David Forsyth for keeping our website regularly updated. We have also focused on increasing our community engagement initiatives. This year, the IWR had a stand at the SciFest Africa, showcasing the work of the Institute. The Institute continues to maintain its anchor community engagement initiative, the miniSASS demonstration of river health with school children, hosted by Ms Khaya Mgaba.

In conclusion, I wish to express my gratitude to all the staff, students and Research Associates of the Institute for their continued support. I especially thank Mrs Juanita Mclean for the huge amount of work she does on a daily basis to keep the work of the Institute going.

Associate Professor Nelson Odume
Acting Director: Institute for Water Research

Mr Siyabonga Mazibuko during Faculty of Science Open day

Ms Aphiwe Magwala facilitating in the first Sustainable Development Goals and Urban River Governance Workshop

Aphiwe Magwala and Miracle Ososh interacting with primary school students during the 2022 Scifest.

ARUA WATER CENTRE OF EXCELLENCE REPORT

The African Research Universities Alliance (ARUA) Water Centre of Excellence (CoE) is a network of nine research Intensive Universities in Africa led by Rhodes University. The collaboration consists of six African Universities: Addis Ababa University, Ethiopia; Makerere University, Uganda; Cheikh Anta Diop University, Senegal; University of Lagos, Nigeria; University of Rwanda, Rwanda; and the University of Dar es Salaam, Tanzania. Additionally, two South African Universities (besides Rhodes University) collaborate on projects: the University of KwaZulu-Natal [UKZN], and the University of Cape Town [UCT].

The larger mandate of the ARUA network is to increase the quantity and quality of African research outputs, and we have worked intensively with students and early career researchers across the network to build their research capacity in terms of research design, implementation, analysis and finally, publication of the work.

The year 2022 saw a significant change in the CoE with the retirement of the ARUA Water CoE director Prof. Tally Palmer who led the CoE in research which focused on Complex Social-Ecological Systems, designed to address 'wicked' problems with transdisciplinary approaches. This was a new field of research for the majority of the partners, but it was one which resulted in a unique learning experience for everyone and shifted views beyond the strongly siloed disciplinary structure that most of our institutions follow. The CoE is grateful to Prof. Palmer for her leadership, and for her humour which has made the journey all the more enjoyable.

The current main funder of the CoE is the United kingdom's Research and Innovation (UKRI) funding agency. The UKRI awarded a capacity-building grant to all ARUA's 13 CoEs, and a Research Excellence Grant to four of the CoEs, of which the IWR was one.

This Annual Report provides details of the two UKRI-funded projects under the Adaptive Water Resources Management section – one that will come to an end in March 2023m and the other at the end of December 2023. In 2022, the project teams ran training sessions in Makhanda as well as a series of workshops in the case study countries.

The CoE has built up significant research capacity within the IWR, including:

- Appointing Dr Sukhmani Mantel as Academic Manager of the Water CoE;
- Appointing Ms Margaret Wolff as Research Development Manager for the IWR. She is instrumental in identifying research opportunities, and assisting with grant applications for the IWR;
- Supporting five Post-Doctoral Fellows in 2022: Dr Matthew Weaver, Dr Notiswa Libala, Dr Bukho Gusha, Dr David Gwapedza and Dr Rebecca Powell;
- Supporting nineteen research assistants at all the partner institutions (most of whom were students).

In mid-2022, we said farewell to Dr Notiswa Libala who took up a permanent position at the Western Cape Economic Development Partnership. We wish her all the best in her position.

While our UKRI grants have been all-consuming, we have also been involved in some other partnerships and projects:

- The National Research Foundation Transformative Social Learning Community of Practice (TSL CoP), which aims to enable social learning to strengthen connections and collaborations for sustainable development. The CoP comprises a cohort of South African Research Chairs Initiative (SARChI) members working on various project sustainability-related work-streams (the UKRI RESBEN Project being one). Collaboration through the CoP enables support, cross-learning and amplification of work to catalyse greater meaningful impact for policy, science and society.
- Collaboration with the Water Security and Sustainable Development Hub based at Newcastle University in the UK which has included participating in webinars, and sending students to courses run by the Hub.
- Contributing to the Peer-Learning for Emerging Researchers' Knowledge and Advancement (PERKA) project which was a joint participatory research project focusing on support provided to early-career researchers in the post-PhD phase in Africa. Funded jointly by the Carnegie Corporation of New York (CCNY) and the National Research Foundation (NRF) of South Africa, the project was implemented in collaboration with the Centre for the Advancement of Scholarship (CAS) at the University of Pretoria (UP), South Africa.

Two of our research assistants (Mr Gyaviira Ssewankambo from Makerere University, and Mr Tekuamework Fikadu from Addis Ababa University) are about to publish their project work and a number of researchers and research assistants are also close to submission. In the near future, two new researchers, Dr Rebecca Powell (previously a Post-Doctoral Researcher) and Dr Rebecka Henriksson, will be working on research profiles within the Centre. Our Youtube channel (**https://www.youtube.com/@aruawatercoe**) provides an overview of some of the work we are doing within the CoE.

Taking over the leadership of the Water CoE from Prof. Tally Palmer has meant big shoes to fill, but, together with the CoE researchers, we have a clear idea of our goals and what we would like to achieve. The ARUA network will continue to highlight African research, breaking down the barriers many African researchers face within the international research sphere, and working towards using our research to achieve impact wherever it is needed.

Dr Jane Tanner
Director: ARUA Water Centre of Excellence

CENTRE FOR ENVIRONMENTAL WATER QUALITY (CEWQ) REPORT

The year 2022 ushered in new collaborations with both international and local experts in the field of water quality. Internationally, CEWQ partners in the *Innovative water infrastructure management to increase water security for people, economy and agriculture in Southern Africa - ECWASA* project which is a collaborative BMBF-funded project by Rhodes University, German institutions (Research Institute for Water and Waste Management at RWTH Aachen e.V., University of Stuttgart, Institute for Sanitary Engineering, Water Quality and Solid Waste Management, University of Hohenheim, Institute of Agricultural Sciences in the Tropics, TZW: DVGW-Technologiezentrum Wasser, Gemeinde Ilsfeld, Barthauer Software GmbH, SEBA Hydrometrie GmbH & Co. KG, AUTARCON GmbH), and important South African role players (Department Water and Sanitation, Republic of South Africa, Chris Swartz Water Utilization Engineers, Mercedes-Benz Manufacturing South Africa Ltd, East London, Kouga Local Municipality, Amatola Water, Vincent).

Another international collaborative project, *Cyanobacteria – the missing link in vibriosis spread*, is funded by the Swedish Research Council. This project is a collaboration between Rhodes University, Stockholms Universitet, City of Scientific Research and Technological Applications SRTA-City, Makerere University, Council for Scientific and Industrial Research, South Africa, and the Centre for Agricultural Transformation, Malawi.

The CEWQ is also partnering with a local University, the Durban University of Technology, on a project entitled "*Assessing the impact of different pollution sources on the type of microplastics, associated microbial communities, antimicrobial resistance and transport of microplastics in selected urban rivers in South Africa*". The project is a Water Research Commission (WRC)-funded collaborative project together with other additional reputable institutions: the Agricultural Research Council, and the Norwegian Institute for Water Research. The last two projects have been made possible by the aquatic microbial ecology unit of the Centre, led by Dr Chika Nnadozie, which was birthed in 2020 and continues to grow. The aquatic microbial ecology unit of the Centre owes its success to its collaboration with the SAIAB laboratory, where most of its molecular microbiology work is conducted.

One of our many success stories is encouraging early research leads. Since the arrival of our postdoctoral fellow in 2021, Dr Frank Akamagwuna, the Centre has continued to develop its research capacity and capability in plastics research and functional ecology, and Dr Akamagwuna is currently supervising one student. The Centre also welcomed two new MSc students, Ms Esther Ahuoiza Seriki and Ms Sofia Lazar.

Our project, *"An ecosystem-based climate resilience approach to assure water security in the Amathole District Municipality, Eastern Cape, South Africa"*, funded by the German agency, Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ), has come to a very successful conclusion.

Ongoing research and projects within the Centre

Currently, eight funded projects are ongoing in the Institute, addressing diverse water issues, from sustainable development, ethics, waterborne zoonoses, water and human health, water quality, to water governance. The title for these projects and their funders are as follows:

- *The multiple risk dimensions associated with* Campylobacteriosis *- a key poverty-related disease of South African urban source water environments*, funded by, EDCTP2 programme supported by the European Union and the Fondation Botnar;
- *Sector programme water policy – innovations for resilience (WaPo-RE)*, funded by GIZ;
- *Innovative water infrastructure management to increase water security for people, economy, and agriculture in Southern Africa,* funded by ECWASA, BMBF;
- *African Water Resources Mobility Network* (AWaRMN), funded by the European Education Culture Executive Agency (EACEA);
- *Cyanobacteria – the missing link in vibriosis dissemination*, funded by the Swedish government;
- *SDG-pathfinding: Co-creating pathways to sustainable development in Africa*, funded by the National Research Foundation;
- *African urban complexities and the governance challenges of urban rivers*, funded by the University of Bayreuth;
- *Investigation of the occurrence and risk of*

infection of pathogenic and antibiotic-resistant Campylobacter *species in selected source waters within the Kowie Catchment, Eastern Cape, South Africa*, funded for four years by WRC is nearing completion.

The noteworthy AWaRMN project continues to be the catalyst for collaboration with other institutions both within and beyond the continent.

The Centre remains committed to capacity development and transformation. At the beginning of the year, the Centre welcomed interns, Mr Siyabonga Mazibuko and Ms Zuziwe Precious Naledi Magqwayi, from the Water Research Commission and Department of Science and Innovation internship programme, and Ms Aphiwe Magwala from WESSA Groen Sebenza. We have applied for funding and encouraged two of our interns who have worked hard and shown interest to work further on the projects assigned to them at the Honours and Masters level, respectively.

We remain immensely grateful to SAIAB and the Department of Chemistry for permitting us to use their laboratories to conduct some of our experiments.

Dr Chika Nnadozie, Lead Researcher
Centre for Environmental Water Quality

A river clean up organised by River Rescue with some volunteer IWR students

HYDROLOGY REPORT

2022 has been a successful year for Hydrology with some star students, successes and awards

One of our AWaRMN funded MSc students, Mr Peter Wasswa, has been particularly active in making connections, presenting, and contributing to a range of initiatives, including a paper presentation on climate change in Karamoja sub-region at the Climate,Culture,Peace Conference (January 2022); a paper presentation on GRACE-based approach for hydrological drought characterisation in Uganda at the Second IGAD Water Dialogue Forum (January 2022); virtual attendance of the Third African Peer Review Mechanism (APRM), a Continental Youth Symposium (July 2022); presentation of MSc research on groundwater recharge dynamics at SAHS (October 2022); attending and contributing to the question on the role of African Early Career Researchers in service of SDGs at the YESS, GEWEX and YHS workshop (October 2022, Rwanda), and a paper presentation on groundwater potential for migrants and displaced people in West Nile-Uganda at the Third IGAD Scientific Conference on Migration and Displacement (November 2022, Kenya). From November 2022 up to February 2023, he has been on internship training with Deltares in the Netherlands as a groundwater researcher supporting the African Climate Mobility Initiative (ACMI) to estimate groundwater use in Africa using machine learning and global data sets under the supervision of Dr Ali Meshgi. Peter also won a bronze medal during the Water4Future Hackathon 2023, Montpellier- France. Mr Wasswa is definitely a rising star at the IWR!

Conferences, Keynotes and Awards

As a conclusion to the Panta Rhei decade (2013–2022), the XI Scientific Assembly of the International Association of Hydrological Sciences (IAHS 2022) was held in Montpellier (France) from May 29 to June 3, 2022. A group of six students and staff from the Hydrology Unit were in attendance. All the representatives successfully presented parts of their research in different workshops and sessions that focused on the subject and its interfaces with other scientific fields and societal challenges. Robust ideas from the unit were presented in high-level panel discussions and plenary sessions to steer the conversation towards increased inclusivity of the African continent in terms of partnerships and collaborations as the IAHS ushers in a new decade.

The inaugural South African Hydrology Society (SAHS) conference was held in Johannesburg from 10–12 October 2022. SAHS is a 'new' society born from the South African National Committee of the International Association for Hydrological Sciences (SANCIAHS). Therefore, we can generally regard the new SAHS body as a rebranded SANCIAHS. The SAHS was born at the conference in Johannesburg, where a general meeting was convened, and delegates voted in the society constitution, code of conduct and a new committee.

The new committee is chaired by Dr Tendai Sawunyama, a Rhodes University and IWR alumni. Members of the committee included officials from the government, consulting practitioners, and members of academia. Professor Emeritus Denis Hughes is also a member of the SAHS committee. The inaugural SAHS conference was graced by guests of honour Director General of DWS, and the CEO of the WRC who emphasised the importance of scientific principles for water resources management and the necessity of professionalising the public service.

The conference kicked off with keynote addresses given by several renowned hydrologists, including Professors Hubert Savenije and Denis Hughes. The lead hydrologist at the IWR, Dr Jane Tanner, gave an inspiring keynote talk on integrating society into hydrology and related challenges. The IWR was well represented at the conference, with eight delegates and an additional cohort of three coming from various African countries under the ARUA Water CoE.

IWR students, PhD candidate Sinetemba Xoxo and Honours student Esihle Gotye, contributed to the poster session at SAHS. The IWR team was elated by the award for the best poster to Esihle Gotye, while Gyaviira Ssewankambo, an ARUA Water CoE MSc student based in Uganda, won the best oral presentation.

Another AWaRMN funded student, Ms Harriette Okal, represented Kenya at the World Youth Parliament for Water (WYPW). Harriette is pursuing a PhD in Hydrology at the IWR. The World Youth Parliament for Water was attended by 59 youth representatives from around the world, to advocate for youth inclusion at all levels of decision making for the realisation of SDG6. A two-part event consisting of the 5th WYPW

Peter Wasswa at Deltares in the Netherlands

MSc student Peter Wasswa at Deltares during his three-month internship in the Netherlands

IWR/ARUA Water CoE delegates attending the inaugural SAHS conference in Johannesburg

General Assembly and the 9th World Water Forum was held in Dakar, Senegal from 16–26 March 2022. The end-goal of contributions to deliberations was to support youth-led organisations and initiatives that propel the realisation of global, regional, national or sub-national policy or development goals such as the SDGs and the AU Agenda 2063. The WYPW are also currently working with other youth groups (Water Youth Networks and UN1FY) in expressing youth concerns that will be presented at the UN Water Conference in March 2023. We came up with the 30-30-30 initiative that seeks to have youth (below 30 years) have at least 30% representation in decision-making tables by 2030. In partnership with the International Secretariat for Water and the and other key partners, the #WaterGeneration (https://youthforwater.org/) attended several forum events and processes to train the water youths as vectors of change.

Graduation

This has been an exciting graduation year since Rhodes University hosted graduation celebratory ceremonies for the 2020 and 2021 graduates who had graduated virtually, and thus were not able to participate in an in-person event due to COVID-19 restrictions. In April 2022, Ms Bawinile Mahlaba completed her MSc thesis in Water Resource Science under the supervision of Dr Mantel and Dr Tanner.

In October 2022, several Hydrology supervised postgraduates received their in-person graduation certificates, including David Gwapedza (PhD), Zwido Lidzhegu (PhD), Eunice Makungu (PhD) and Sinethemba Xoxo (MSc).

Research Directions and Collaborations

Following Prof. Tally Palmer's retirement at the end of June 2022, Dr Tanner stepped in as the Project Primary Investigator for the UKRI-GCRF-funded ARUA Water Centre of Excellence (CoE). This change was approved by the Project Board, UKRI, and has been supported by all the Water CoE nodes. Prof. Palmer continues to work with Dr Tanner during the transitionary period and she will remain involved for a meeting in Uganda in 2023 where the node co-investigators and social science supervisors will gather to write up and reflect on the project and the way forward. Read more about it under the ARUA Water CoE project report.

We were sad to see Dr Kathleen Smart leave the IWR for a post at South African Environmental Observation Network (SAEON) as an Expanded Freshwater and Terrestrial Environmental Observation Network (EFTEON) Landscape Scientist. It is an excellent opportunity for Dr Smart as she fits the needs of the EFTEON network perfectly. During the past few years, she had worked with Prof. Anthony Palmer on using the NRF-funded Eddy Covariance equipment to evaluate the landscape water and carbon exchange in grasslands. In April 2021, she was also appointed as Project Lead for a Water Research Commission project that is looking into water use of *Cannabis sativa* (Hemp) in the Eastern Cape and KwaZulu-Natal provinces in collaboration with University of KwaZulu-Natal. This is a new area of research for the Institute and it is a project whose outputs will support rural community livelihoods. Previous research in South Africa has found that for some communities, rainfed cannabis production can contribute substantially to their income. On Dr Smart's departure, Dr Sukhmani Mantel stepped in as Project Lead for this WRC project starting from July 2022. Read more about this project under the Hydrology section reports.

Community engagement

Several students, including Peter Wasswa, have been joining up for river cleanups by River Rescue. Our deepest thanks to these students who go out of their way during their free time to contribute to make the 'rivers sing' according to Helen Holleman, the organiser of River Rescue.

Dr Jane Tanner and Dr Mantel have initiated a collaboration with *Amanzi Water to Schools*, a US public charity group, founded by Julia Heemstra (https://amanzi2schools.org/about-us). The collaboration relates to evaluating and designing a water harvesting system for a school in Riebeeck East with approximately 110 learners and staff. The public charity group is sponsoring the installation of waterless toilets and is hoping that the rainwater harvesting system will provide sufficient water for drinking water, a school nutrition programme and handwashing, in addition to supplying each learner with 5 L of water to take home daily during the school year. The project will use a rainwater harvesting model developed by Prof. Denis Hughes that provides an estimation of how much water can be reliably provided using information about daily rainfall, roof area, tank(s) volume, and daily usage. The installation of the water tanks is expected to begin in early 2023.

The Hydrology group is also actively submitting proposals (two were submitted in 2022) so that IWR can formally work with non-governmental groups.

Dr Jane Tanner
Head: Hydrology

ARUA Water COE Director Dr Jane Tanner standing next to Dr David Gwapedza and the two winners of best poster, Ms Esihle Gotye, and oral presentation award winner, Mr Gyaviira Ssewankambo

Dr David Gwapedza (PhD Hydrology; centre left) and Mr Sinethemba Xoxo (MSc Water Resource Science; centre right) with their supervisors (from left) Prof. Denis Hughes, Dr Jane Tanner, Dr Alta de Vos (Department of Environmental Science) and Dr Sukhmani Mantel

Congratulations to Ms Bawinile Mahlaba on her MSc graduation

Some of the IWR graduates from 2020 and 2021 who received their certificates in person in October 2022 (Dr David Gwapedza, Dr Zwido Lidzhegu, Dr Frank Akamagwuna and Mr Sinethemba Xoxo)

(left) Harriette Okal. (right) World Youth Parliament for Water representatives from 59 countries across the globe.

IWR CITIZEN SCIENCE GROUP REPORT

The Centre took learners from Ntsika High School on a mini-SASS demonstration in the Bloukrans River (Grahamstown). Learners were exposed to the complexity of water quality challenges, and the responses of aquatic biota to water pollution. The purpose of this activity was to teach the learners to understand how water pollution affects freshwater organisms, and the role they can play to prevent water stress and water scarcity in their communities.

Ntsika high school students during mini-SASS field trip (top) and Mr Enahoro Awowenu engaging a high school student during the training (bottom)

BUILDING CAPACITY THROUGH INTERNSHIP TRAINING

In 2022 IWR has hosted two interns funded by WESSA and the Water Research Council (WRC).The internship training involves a variety of scientific, community engagement and facilitating workshops supervised by staff of the Centre for Environmental Water Quality (CEWQ). The current supervisor Dr Chika Nnadozie and Prof Nelson Odume. Ms Aphiwe Magwala and Siyabonga Mazibuko secured an internship position at IWR, from December 2021 to December 2022. Through this programme, they have gained skills and understanding in biomonitoring, ecotoxicology, chemical analysis, maintenance of animal culture for toxicity testing, microbial experts and facilitating workshops. As part of this training, they assists with field and laboratory experiments for both staff and postgraduate students.

Ms Aphiwe Magwala facilitating in the first Sustainable Development Goals and Urban River Governance Workshop (top) and Mr Siyabonga Mazibuko culturing Campylobacter species (bottom)

Community engagement at the IWR 2022

SciFest Africa was established to promote the public awareness, appreciation and understanding of science, technology, and innovation. The 26th consecutive National Science Festival theme for 2022 was "Back to the Basics", inspired by UNESCO's International Year of Basic Sciences for Sustainable Development 2022. SciFest Africa highlighted the crucial role of basic sciences, technology and innovation in South Africa for sustainable development, emphasising their contribution to the implementation of the 2030 Agenda and achievement of the Sustainable Development Goals. The Institute for Water Research (IWR) used this opportunity to give back to the community and share the knowledge gained through scientific studies. The IWR post-graduates and staff showcase the work conducted by the Institute, focusing on water sustainability and highlighting the three pillars of the National Water Act: Equity, Sustainability and Efficiency

Mr Aphiwe Magwala and Miracle Ososh interacting with primary school students

Enahoro Awowenu and Andrew Ali during Sciefest 2022

The IWR uses this opportunity to give back to the community and share the knowledge gained through scientific studies. The Institute has a history working with different projects in the Kat River Catchment, and this year they visited KRC to give back by training the catchment forum members to use the river health monitoring tool, miniSASS.

Khaya Mgaba helping Kat River forum members to interpret the miniSASS score.

Postdoctoral Fellow activities

ARUA Water Centre of Excellence

B Gusha and JL Tanner

Sponsor: ARUA-UKRI Water Centre of Excellence (CoE)

Research Aim:

The overarching goal of the research is to develop a recommendation to ensure sustainability of watersheds rehabilitated through community mobilisation in Ethiopia following the Adaptive Systemic Approach (ASA).

Research objectives:

- To assess the state of biophysical rehabilitation in the study watershed, and in consultation with the community, to design strategies for rehabilitation or enrichment.
- To evaluate (map) the interplay between landscape (ecosystems) and socio-economic activities in the learning watersheds.
- To enhance awareness (capacity) of watershed community for resilient ecosystem services.
- To explore the meaning stakeholders attach to power relationships as they unfold through the ASA steps.

So far, an Adaptive Systemic Approach has been successfully held by the node, where stakeholders from two watersheds, Aba Gerima and Debre Yakob, had an opportunity to share ideas and learn from one another.

Learning exchange during the APP workshop in Ethiopia

A postdoctoral update

D Gwapedza and JL Tanner

Sponsor: ARUA-UKRI Water Centre of Excellence (CoE)

2022 has been a busy year with bittersweet moments, but fulfilling overall. I have been involved in several projects besides the WRC project that I lead. One of the projects is the African Research Universities Alliance, where I am engaged at the Water Centre for Excellence at the IWR. Here I work with a Uganda-based Masters' student registered at Makerere University. At Rhodes University, I supervise a Masters and an Honours student and provide mentorship to several other students. Additionally, I lead the Honours hydrology course, which I jointly teach with Drs Jane Tanner and Sukhmani Mantel.

I have conducted some hydrological modelling consultancy work with Dr Tanner, which involved training Department of Water and Sanitation (DWS) officials on using the Water Quality Systems Assessment Model (WQSAM) model. The work enabled us to develop a working relationship with officials from the DWS water quality section. In May I attended a Companion Modelling (ComMod) training workshop in Montpellier, France. This was followed by the International Association for Hydrological Sciences (IAHS) conference, where I presented stakeholder engagement and modelling work I am involved in. In August 2022 I was involved in co-facilitating an Adaptive Planning Process (APP) workshop in Kampala, Uganda. The APP workshop is part of a series of stakeholder workshops that are part of the ARUA project. The last quarter of 2022 will involve working with postgraduate students to submit their theses, and more stakeholder workshops.

A group discussion during the ComMod workshop in Montpellier.

Hydrology Honours field trip in July 2022.

Supporting the ARUA RESBEN Project's nodes: Lagos and Rwanda

N Libala and CG Palmer

Sponsor: ARUA-UKRI Water Centre of Excellence (CoE)

My primary responsibility was providing operational support, including close communication and feedback, arranging and coordinating node meetings, and helping research assistants from the Nigerian and Rwandan nodes write their papers. I was also responsible for organising the Writing Community of Practice sessions and I am involved in organising and facilitating workshops.

Activities in 2022

ARUA Water Centre of Excellence Strategic Adaptive Management training and Adaptive Planning Process workshop

From January to June 2022, I worked as a post-doctoral Researcher in the ARUA Water Centre of Excellence, funded by the United Kingdom Research and Innovation (UKRI). This is a collaborative project that involves researchers from Rwanda, Nigeria, Tanzania, Uganda, South Africa, Ethiopia, Senegal, and the United Kingdom. As a part of this project, we were required to conduct workshops for the nodes which hosted place-based case studies.

From 7– 9 February 2022, I travelled to Rwanda to support our partners at the University of Rwanda to plan and facilitate the Adaptive Planning Process (APP) workshops. The purpose of the workshops was to provide an opportunity for stakeholders to meet one another, hear each other's perspectives, see the potential of collaboration in relation to integrating bio-indicators into the commonly used water quality assessment tools, and to demonstrate how research can be useful in support of collaborative action.

In June I co-facilitated the Strategic Adaptive Management (SAM) training workshop for all the nodes, the purpose of which was to build the capacity of the RESBEN project members (nodes, learning sites and the hub) to better understand SAM, how it fits into the Adaptive Systemic Approach (ASA) and how to progress their stakeholder engagement process through SAM.

Adaptive Planning Process debrief session facilitation and planning

In April 2022, I was involved in several planning meetings for the APP debrief session. On 5 May 2022, I was a lead facilitator in the APP debrief session that was attended by all the nodes working on the RESBEN project. The purpose of the debrief session was to provide a mutual learning opportunity to share successes, challenges, and adaptations that were experienced by the node who had already facilitated the APP workshops. The insights of the discussions were intended to inform the design and facilitation of upcoming APP workshops as well as strengthen the SAM methodology.

Water Research Commission (WRC) Project

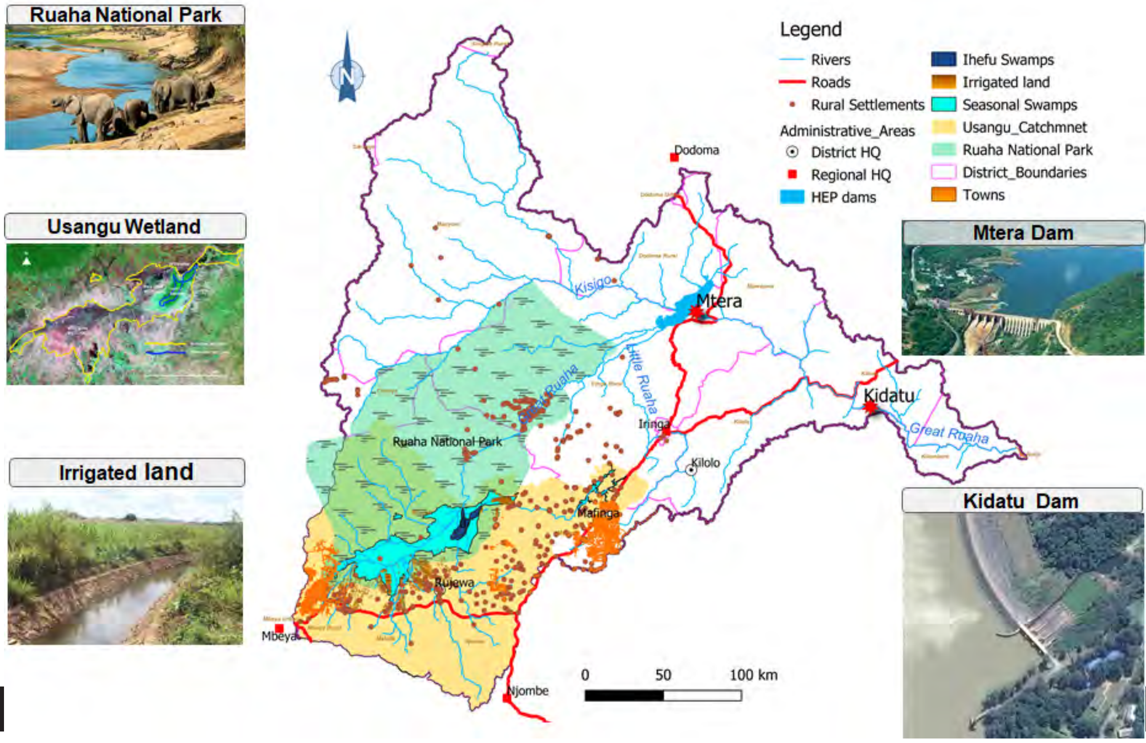
I am a reference group member for a WRC project that investigates promoting the adaptive capacity of rural communities to climate change. I am also involved in a WRC project that focuses on using citizen science to protect natural untreated drinking water sources.

Understanding African water challenges from multiple perspectives

R Powell and JL Tanner

Sponsor: ARUA-UKRI Water Centre of Excellence (CoE)

As a post-doctoral research Fellow, during 2022 I have primarily worked on research topics which serve to deepen collaborative understanding of some of the water supply-related challenges we face in southern Africa. Firstly, I worked in collaboration with research partners from Tanzania, University of Dar Es Salaam, under the ARUA- UKRI Water Centre of Excellence (CoE) hosted in the IWR. My role in this case, with inputs from Dr Jane Tanner and Dr Ana Porroche-Escudero from the CoE, has



The Ruaha River Basin showing different water users competing for a stake in sufficient access to water (Source: Miss G Mollel: Tanzania Research Team)

been to provide guidance on case study research design and implementation. I worked with Dr Jane Tanner to develop a detailed research proposal aimed at improved water supply augmentation in Makhanda (formerly Grahamstown), where Rhodes University and the IWR is based.

Understanding water equity in the Tanzania Ruaha Basin

The Tanzania case study investigates issues of equitable access to adequate and safe water by rural communities and aquatic ecosystems of the Great Ruaha River Basin in Tanzania. The Basin hosts the world-renowned Great Ruaha National Park, important rice-producing areas, and hydropower plants that supply electricity to major towns. There are strong tensions between these competing water users.

The aim of the research project is to investigate several scenarios for more equitable water allocation in the Basin and how marginalised stakeholders of water could be included in decision making around water allocation. Using the WEAP model (Water Evaluation and Planning Model) and focus group discussions with Basin stakeholders, the research project has developed several improved water allocation scenarios. Although these scenarios are useful for supporting better management and allocation of water resources in the Ruaha Basin, they shed little light on the differences in power that various water users and water management institutions hold with regard to water allocation. The project has therefore set out to gather the stakeholders together to start building relationships and breaking down barriers to inclusion in decision making. One of the key successes of 2022 was the development of a shared vision for the Basin by the stakeholders, including large industry, the Basin Water Committees, Water User Associations, small scale farmers and government departments.

Improving water supply management at Makhanda (Grahamstown)

Dr Jane Tanner and I submitted a Water Research Commission action research proposal that investigates improved water supply augmentation in Makhanda. The town has experienced severe droughts and water crises, with the present-day crisis being declared in 2013. The response of the University and town to the present water crisis has consisted of a series of small-scale, ad-hoc interventions, that have not been carefully planned, integrated or maintained, leading to an overall inefficient approach to the development and utilisation of the scarce water resources. The project aims to develop a groundwater to surface water augmentation and monitoring system for improving water supply reliability in Makhanda West, where Rhodes University and the IWR is located. The system will be designed with involvement and knowledge inputs from water managers and technicians from the local municipality and Rhodes University, local water scientists, professionals, and NGOs fighting for marginalised community members.

Using the Makhanda case, a simple guide to designing effective and sustainable water augmentation solutions for other small, drought-prone towns will be developed. If successful, this two-year research project could be a critical step in the journey of improved decision making and effective action on the water crisis in Makhanda.

Capacity development and evaluation in the ARUA RESBEN project, a multi-collaboration transdisciplinary research project.

MJT Weaver and JL Tanner

Sponsor: ARUA-UKRI Water Centre of Excellence (CoE)

Overview of my role

My research interest lies in sustainable landscape transformation which mostly involves working with complex resource problems located at the interface(s) of social and ecological systems. Learning, particularly learning that is social, transformative, and transgressive is central to catalysing transformation and making a difference at these interfaces. Through my post-doctoral Fellowship, I have been fortunate to drive, support and research learning processes in two multi-collaboration research processes, the ARUA and Tsitsa Projects. I am contributing to several linked transdisciplinary research processes related to social learning facilitation capacity development and evaluation, strategic adaptive management, governance, capability expansion, and integrated landscape rehabilitation planning. Below I briefly outline the highlights of my involvement in the ARUA Project. A proposal has been submitted and accepted to conduct final closure work on the Tsitsa Project. This work has not commenced and is therefore not reported on here.

The ARUA project

I am leading evaluative research with and of the Resilient Benefits (RESBEN) Project driven by the ARUA Water Centre of Excellence. The research is entitled: "Exploring the impact of learning catalysed from participation in the Resilient Benefits Project: A value creation approach". This research project aims to explore the value catalysed for coordinators, facilitators, participants and stakeholders from their involvement participation in the Project. The RESBEN Project implementation is informed by the Adaptive Systemic Approach (ASA) which is being effected through a series of social learning engagements, which cumulatively seek to support engaged social-ecological research processes across six African Case Studies. The impact of the Project can be evaluated by exploring the different forms of value catalysed for participants as they engage in the collective social learning engagements facilitated through the course of the Project. We understand value as individual and collective experiential, potential, application, impact, enabling, transformative, orienting, and strategic benefits gained by participants through their engagement in the Project. Value-creation-related data is being collected through observation within group engagements, reflection survey results after engagements, analysis of project outputs and key informant interviews. This research will provide a fine-grained and nuanced understanding of the typically hidden and undocumented value for participants catalysed by the Project beyond what was outlined in the objectives and what was promised as deliverables. Flows of value catalysed in project learning spaces indicate a far broader scope of impact than measured and reported on through conventional evaluative approaches. By focusing on value created as a measure of impact, projects can showcase and promote the real, modest, but lasting impact of transdisciplinary interventions in complex Social Ecological Systems.

Capacity development and stakeholder engagement

Following on with the Adaptive Planning Process (APP) Training of the Trainers Workshop that I coordinated and co-facilitated in September 2022, I co-planned and co-facilitated a Strategic Adaptive Management Training of Trainers workshop for all nodes of the RESBEN project. This workshop took place over four days from 20–24 June 2022. This critical capacity development process was to

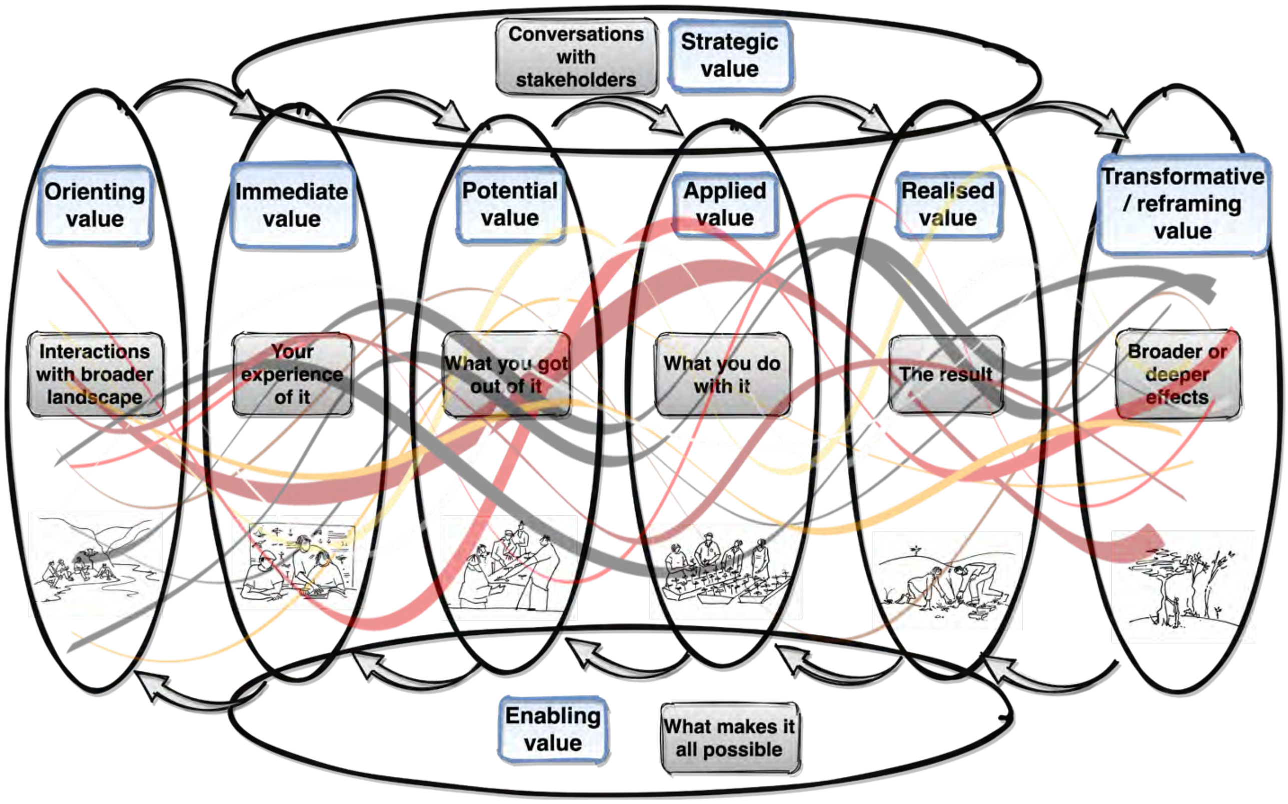


Figure 1: The cumulation of different value flows (value creation stories) from different individuals collectively provide a more complete picture of value and impact catalysed by the RESBEN Project.

enable the continued implantation of the Adaptive Systemic Approach across the six African country nodes. Participants left the training with increased capacity to facilitate stakeholder co-development of management objectives, implementation plans and monitoring and evaluation plans in their own contexts (the next steps of Strategic Adaptive Management). Some node participants were still planning their APP workshops and used the time to further develop these, drawing on lessons learnt from past APP workshops. I have supported the planning and design of six APP workshops, all of which were successfully implemented in Node countries (Nigeria, Senegal, Tanzania, Rwanda, Uganda, and Ethiopia). I travelled to Rwanda, Ethiopia and Cape Town to co-plan and co-facilitate their APP workshops. Learnings and lessons from the facilitation of these workshops are being distilled and contributing to two journal articles that I am co-authoring

I am working with Dr Nadia Sitas (Stellenbosch University) and Dr Jessica Cockburn (RU) as editors of an *Ecosystems and People Special Issue*, **Advancing transdisciplinary research on transformations in social-ecological systems in the Global South.** This editorial work has been a rich learning curve for me, and I have a renewed appreciation for the back-end process journals and editors go through to see a manuscript through to publication.

Lastly, I am supervising three students, two MSc and one Honours student. Anele Tshangase, an MSc student based at the IWR, conducts her research within the Tsitsa Project. She is exploring the value of ecological infrastructure related to participatory governance processes in the Tsitsa River catchment. Kwanele Siyengo is an MSc student whose work falls within the SANBI Living Catchments Programme. Her thesis title is: "Understanding and supporting the practice of facilitating social learning and stakeholder engagement for catchment management in the South African context: A case study in the Umzimvubu and Olifants catchments". Lastly Thembalami Mazibuko is an Honours Student whose work falls within a Water Research Commission Project: Using Citizen Science to Protect Natural Untreated Drinking Water Sources: Natural Springs in Rural Catchments and B3 Municipalities in the Eastern Cape. Her thesis title is: "Exploring effective learning and capacity development processes for citizen science tools in monitoring and sustainable use of springs, Eastern Cape, South Africa".Z

Hydrology projects

A stakeholder-driven process to develop a more equitable and sustainable water resource management plan

D Gwapedza, JL Tanner and SK Mantel
April 2021 – March 2024

Sponsor: Water Research Commission
Collaborators: B Paxton (FRC, South Africa), O Barreteau (INRAE, France), B Bonte (INRAE, France)

Water scarcity is a significant problem in South Africa. Low average rainfall results in limited water available for human and environmental needs. The water availability situation has received further shocks from droughts and the increasing impacts of climate change. The South African National Water Act (Act 36 of 1998) and Water Services Act (Act 108 of 1997) were instituted to manage human water use and protect the environment by establishing Environmental Water Requirements (EWR). An EWR stipulates the amount of water needed to ensure that a river system remains functional and sustainable. However, due to low rainfall in many areas, water-holding areas (catchments) retain too little water in rivers and reservoirs, barely meeting human and environmental needs.

Consequently, competition for water resources is increasing and has resulted in water-related conflicts among water users in many areas of South Africa. Unfortunately, when competition for water use exists, EWRs are often ignored, thus impacting the health of riverine ecosystems. This project responds to this problem by negotiating a shared water management strategy that achieves equity in water access and respects the EWR. While the problem exists in many regions of South Africa, the project focuses on the KoueBokkeveld (KBV) region, Western Cape, where the problem is prominent. Conflicts are rife between upstream farmers with initial access to river water and downstream farmers who are forced to use what remains after upstream users satisfy their needs (Paxton & Walker, 2018). Unfortunately, the numerous dams have led to a depletion in EWR supply and threaten riverine ecosystems and the various plant and animal species that depend on the river systems (Paxton & Walker, 2018).

The situation entrenches inequality and fuels conflict and, if left unmanaged, may turn into an environmental disaster (e.g., there are several endangered endemic fish species in the rivers) and lead to a breakdown in relationships in the farming community. Additionally, the potential loss in agricultural productivity will affect local food security, the economic return from exports, and the livelihood of the thousands of farmworkers who work in the area. Effective water management is vital to ensure equity in water access to foster shared growth, reduce water conflict, promote ecosystem health, and prevent biodiversity loss. This project aims to assist the KBV stakeholders in co-developing a water resources management strategy that results from a shared understanding of the catchment. The specific aims are to:

1. Work with/build relationships between stakeholders while expanding their understanding of the bigger picture of water resource use and management in their catchment;
2. Negotiate a sustainable and equitable water management plan that observes environmental water requirements and protects riverine biodiversity;
3. Explore scenarios of future water demand for growing agricultural development and water availability under climate change to adapt the water management plan to a set of anticipated scenarios ensuring sustainability under change.

A mixed-methods approach will be adopted in this research following multiple disciplines. Hydrological, ecological, social, and computer sciences converge to fulfil the project aims. Hydrological and ecological data will be used to set up an Agent-Based Model (ABM), the principal tool used for negotiation support within the project. Social science principles will be adopted in stakeholder engagement through various methods that include workshops and interviews.

Three institutions are collaborating on the project: the Institute for Water Research–Rhodes University (IWR-RU) South Africa specialises in hydrology and water governance; the Freshwater Research Centre (FRC) South Africa specialises in ecology, conservation and stakeholder engagement within the KBV; the National Research Institute for Agriculture, Food and the Environment (INRAE) France specialises in developing ABM models and agricultural sciences. The project is scheduled for three years. Three postgraduate students are part of the project: Sinetemba Xoxo (PhD), Sakikhaya Mabohlo (MSc), and Stefan Theron, (MSc).

Progress so far

Significant progress has been made so far in fulfilling project objectives. Progress can be split into two categories: modelling and workshops.

Modelling

Hydrological modelling using the SWAT model is almost complete. The natural flows needed for ABM modelling are already available from the hydrological model. MSc student Mr Sakikhaya Mabohlo, conducting the hydrological modelling, is finalising his MSc. Agent-Based Model development has commenced, and conceptual ABM models have been developed, including class diagrams and activity diagrams communicating the model structure and elements. A desktop model of the catchment system is currently being developed for sharing with stakeholders at a workshop in November 2022. MSc student Mr Rodney Tholanah is performing ABM development as part of his computer science Master's degree. Mr Sinetemba Xoxo is developing a water-sharing tool as part of his PhD. The water sharing explores water sharing in the context of uncertainty. An additional water balance model developed for operational use at the farm level is part of the suite of models applied within the project (see Figure 1).

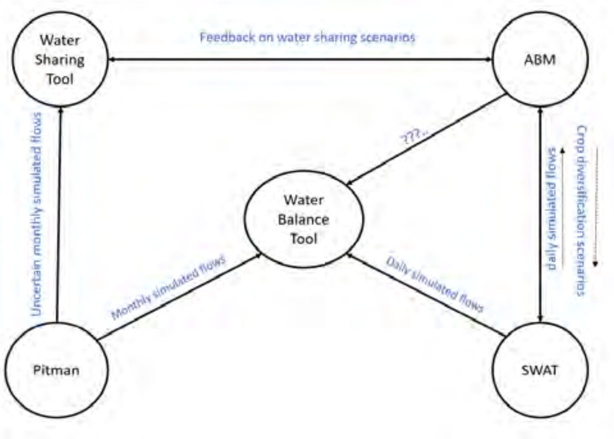


Figure 1. Image showing the models applied and their interactions.

Table 1. A list of Actors, Resources, Dynamics of the catchment as listed by the stakeholders.

Actors	Resources	Dynamics
Direct actors:	• Sun (Temperature, Evaporation, Photosynthesis)	• Value of crop
• Farmers	• Minerals	• Irrigation
• Resident/Farmer	• Soil (Quality, type)	• Job creation
• Eco-tourism operator	• Indigenous vegetation	• Water restrictions
• Permanent labour	• Wetlands (extent /coverage)	• Development of infrastructure
• Seasonal labour	• Wild animals	• Markets
	• Vegetation (healthy coverage)	• Declining fish population
Indirect actors:	• Biodiversity (diversity of species. Rare endangered)	• Expansion of IAPs
• Water Users Association	• Natural beauty (tourism income, enjoyment, beauty)	• Mining
• DWS	• Skills (inter-generational)	• Soil management
• Reserve management	• Knowledge + Capacity (types of data)	• Crop type, technical advances
• NGO/NPO (FRC, WWF)	• Irrigation infrastructure (cost, water to crop ratio)	• Inter basin transfer
• SARS	• Roads (surface, quality)	• Water abstraction
• LandCare	• Water (usage, quantity, quality)	• Storage of rainwater and distribution networks
• Government (national to municipal)	• Fuel + electricity (cost, availability)	• Housing development
• Retailers/ Buyers (local to global)	• Cultural, heritage sites	• Fires
• ESKOM	• Farming (infrastructure +equipment cost)	• Climate change
• Fertilizer companies	• Waste + pollution	• Environmental flows/reserve
	• Bees (extent of orchard, hives per hectare)	• Expansion of agricultural land
	• Chemicals (regulation, residues, cost)	• Tourism development
	• Groundwater (quantity, quality, flow, location)	• Switch from family to corporate farms
	• Air (quality)	• Herbicide and pesticide use
		• Immigration

Workshops

Several workshops have been conducted so far. Some workshops constituted in-house training for project team members, while one workshop was held in the catchment with stakeholders. Two in-house workshops were conducted this year. The first was conducted in Montpellier, France, and was attended by David Gwapedza, Sinetemba Xoxo and Rodney Tholanah from the South African team. Olivier Barreteau and Bruno Bonte represented the French team. The other workshop was held at Rhodes University and was attended by the entire project team except Bruno Bonte. Karen Bradshaw from the Computer Science Department attended in her capacity as Rodney's supervisor and ABM expert. The workshops with the stakeholders were held in May 2022 and involved gathering data from the stakeholders regarding the catchment Actors, Resources, Dynamics and Interactions (ARDI) (see Table 1). However, the ARDI process was merged with elements of the Adaptive Planning Process (APP) to ensure that stakeholders in the room developed a shared vision and an understanding of the future they envisage in the catchment. The stakeholder workshop was well attended and a second workshop is planned for November 2022.

The next year's activities focus on completing the development of the ABM and holding more stakeholder workshops. The first workshops will be used to showcase and validate the representations with the ABM; this will be followed by exploring various scenarios and identifying a feasible management scenario.

Determine water use of the Cannabis Tree in the Eastern Cape and KwaZulu-Natal provinces

K Smart and SK Mantel

April 2021 – March 2025

Sponsor: Water Research Commission
Collaborators: AR Palmer (IWR), S Gokool (UKZN), A Clulow (UKZN), K Chetty (UKZN), S Tesfay (UKZN), T Mabhaudhi (UKZN), R Kunz (UKZN)

Interest in *Cannabis sativa* as a feasible, high-value crop for emerging small-scale farmers is growing. *Cannabis sativa* is a multi-purpose crop that can be grown for fibre, seed, oil, and medicinal properties, as well as having bioenergy potential, and numerous other environmental benefits, such as phytoremediation. Despite being one of the oldest cultivated crops, little is known about the water use of the crop, except for the consensus that it is a water-thirsty crop.

The project aims to produce new knowledge and information to guide a growing interest in *C. sativa* in response to the changing legal and regulatory requirements, as well as an increasing drive to follow environmentally sustainable development pathways (e.g., bioenergy). Water-use estimates will be determined through field-based trials, and pot experiments. Field-based trials and pot experiment data will be used to parameterise the AquaCrop model, and national scale model runs will be undertaken to provide simulations of crop yield, water use and water productivity. These will be combined with bioclimatic suitability mapping using the Maxent model, with the resultant product mapping areas of high to low *C. sativa* production potential.

Distribution maps of the current areas of *C. sativa* will be produced using high resolution hyperspectral imagery. Additionally, complementary maps of potential target areas for *C. sativa*, where dual environmental and economic benefits may be recognised, will be produced. These aspects will be included in a preliminary framing document to guide stakeholders at all levels and decision makers across the agricultural, water, and development sectors. This project will provide the necessary understanding of the production potential of *C. sativa* and, more importantly, the potential knock-on impacts on the water resources and downstream water availability. Without this knowledge, adequate water provision for citizens and sustainable development could be compromised if continued expansion of *C. sativa* cultivation occurred.

The aims of the WRC project were:

1. To conduct a scoping review of available literature on the water use, distribution and agronomic management and value chain of *C. sativa* crops for both fibre and oil production;

2. To map the extent and distribution of *C. sativa* stands as well as identify suitable growth areas;
3. Determine the water use and yield of *C. sativa* for either fibre or oil production using field-based measurements;
4. Undertake multi-scale modelling of the water use, yield and potential hydrological impacts of *C. sativa;*
1. Undertake a preliminary socio-economic feasibility assessment based on value chain principles, including suitable areas for growth and best management practices.

The project commenced in April 2021. In the past year two deliverables were submitted to the WRC:

Deliverable 3 (Initial *Cannabis sativa* distribution maps)

This deliverable is linked to Aim 2 and included an assessment aimed at demonstrating how the power of geospatial cloud computing can be leveraged to exploit the unique characteristics of Sentinel-2 imagery for the purpose of mapping *C. sativa* within the Eastern Cape province of South Africa. In order to model and predict the seven broad land use and land cover (LULC) classes, some of the commonly used machine learning classification algorithms available in Google Earth Engine (GEE) were deployed. Overall, the best performing classification algorithm was the Gradient Tree Boosting (GTB) classifier, and the average class-specific producer accuracy (PA) and user accuracy (UA) for the GTB classification were 89.29 % (± 9.41) and 89.86 % (± 8.47), respectively. The result of the mapping is shown in Figure 1.

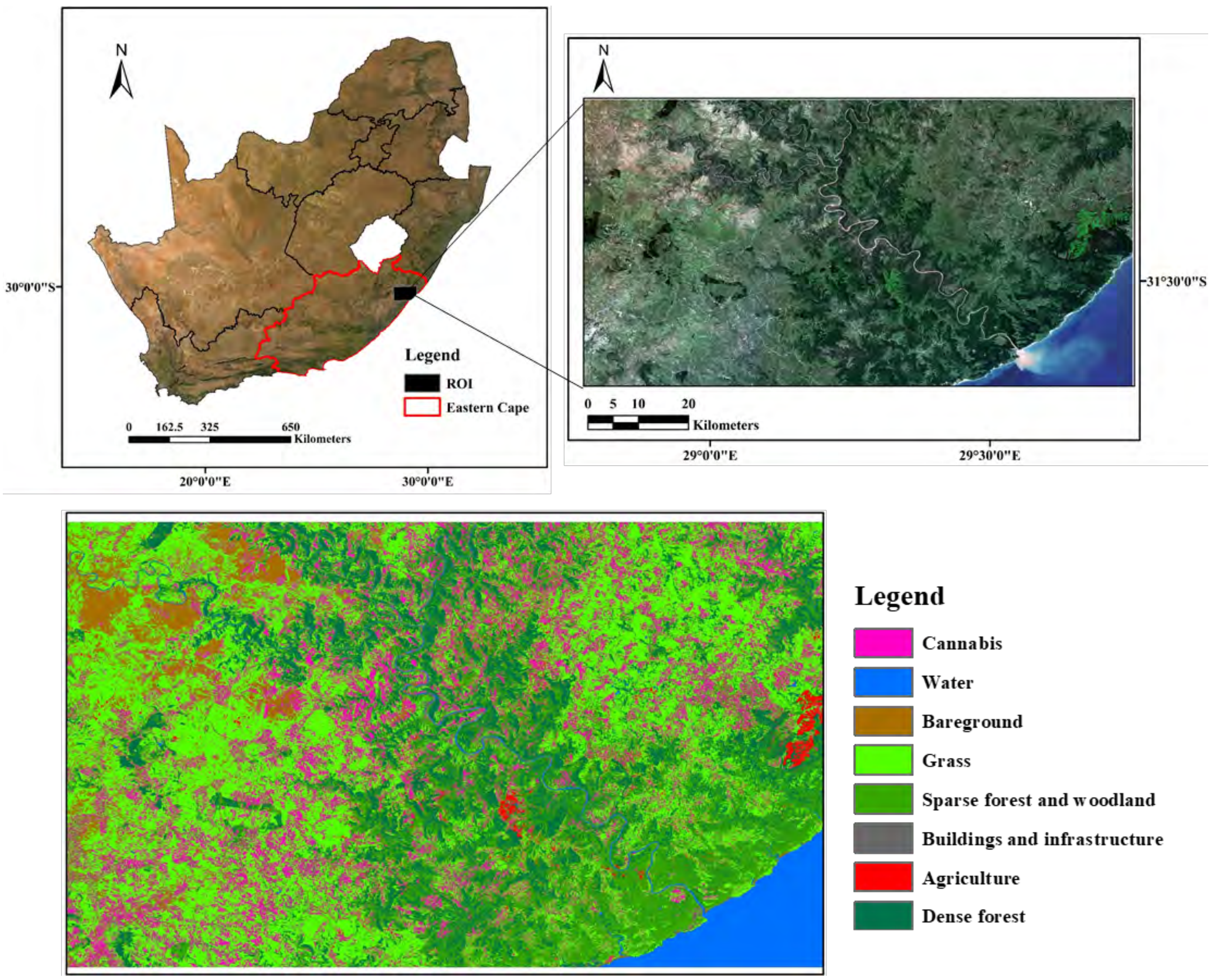


Figure 1. LULC classification result for the study region at a 10-metre spatial resolution, with the Sentinel-2 RGB composite shown on the top right. (Agriculture=Cultivated land, without C. sativa).

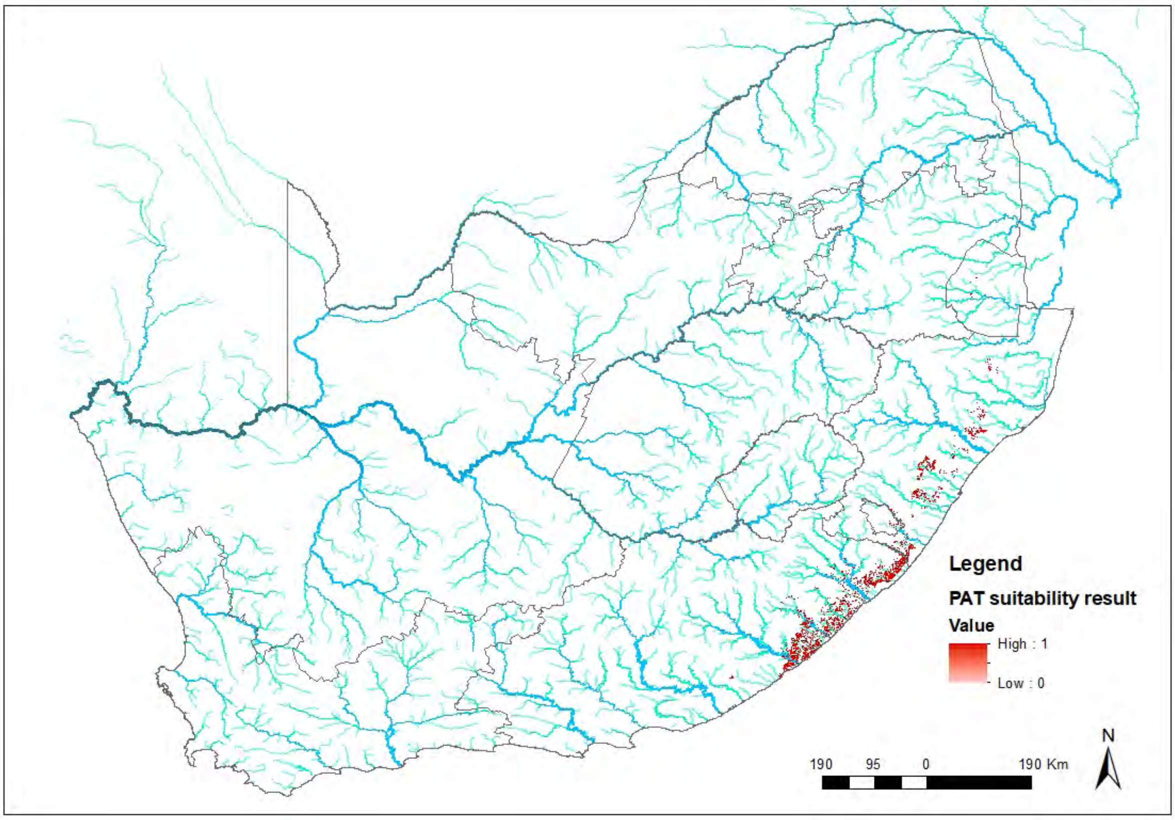


Figure 2. Result generated by the ArcGIS Predictive Analysis Tool for suitable growing areas in South Africa.

Deliverable 4 (Progress on *C. sativa* growth environment report)

Cannabis sativa is the most extensively trafficked and sought-after illicit drug worldwide. This has led to a great deal of interest in mapping *C. sativa* to rapidly and more efficiently detect the growth of illicit plantations which can then be destroyed, ultimately resulting in reduced consumption. However, perceptions regarding the use of *C. sativa* continue to evolve, particularly around its use for medicinal purposes. Improving upon existing detection and mapping techniques has taken on added significance as it allows for improved planning and management of legalised crops that are regulated within certain countries. Thus, this deliverable identified and mapped bio-climatic regions deemed suitable for *C. sativa* production in South Africa using limited ground data and literature guidelines on suitable habitat conditions.

Although hemp is well adapted to the temperate climatic zone and will grow under varied environmental conditions, it grows best in warm growing conditions, an extended frost-free season, highly productive agricultural soils, and abundant moisture throughout the growing season. We mapped suitable growing locations for cannabis in South Africa using two different methods:

i) ArcGIS Predictive Analysis Tool using the climate datasets derived from the South African Atlas of Climatology and Agrohydrology, and
ii) Species distribution modelling using high-resolution, satellite-derived climate datasets in Google Earth Engine.

The result using the ArcGIS Predictive Analysis Tool (shown in Figure 2) indicates that very limited areas are ideal for growing *Cannabis*.

The project supports three MSc projects, with one of them hosted at IWR (Kamva Zenani), and the other two at UKZN.

Application of SWAT hydrological model to simulate catchment water balance: A case study of Twee and Leeu River, Western Cape

Student: S Mabohlo
Supervisors: JL Tanner and D Gwapedza
Degree: MSc (Hydrology)

Water availability in South Africa is affected by numerous and diverse factors. These factors include not only temporal and spatial distribution of rainfall and high evaporation rates but also competition for water resources from expanding irrigated agriculture, industrial and domestic water use sectors. The competition for water from different users results in conflicts over this limited resource. Water-related conflicts are also known to arise within a single water use sector, such as when water use allocations are questionable. For instance, in the agriculture sector, which is the largest (63%) user of available freshwater, water-related conflicts that are largely centred among commercial farmers are commonly experienced. When such conflicts occur, emerging farmers are left without a fair share of water, and the flows are abstracted without considering environmental requirements.

There is a need for targeted, evidence-based water resource management strategies that will ensure equity in water access, reduce water conflicts and account for ecological reserve requirements. Hydrological models are widely applied to facilitate improved quantitative understanding of catchment dynamics that is required to develop sustainable water management plans.

In this study, SWAT+ hydrological model was utilised to model the water balance and future flow scenarios of the Kouebokkeveld catchment. The specific objectives are:

1. To analyse the rainfall information from farmers and weather stations to produce a reliable rainfall surface
2. To set up and evaluate SWAT model performance in simulating water balance for the Kouebokkeveld (KBV) catchment, Western Cape, where there are significant abstractions for irrigation purposes
3. To apply calibrated SWAT model to simulate future flow scenarios under a changing climate.

The hydrology of the Kouebokkeveld catchment is complex; it is characterised by a strongly seasonal flow regime, where winter flash flood flows dominate, and long dry summer periods are experienced. Numerous small dams have been constructed in the catchment to capture the extreme winter flows. The dams contribute additional complexity to the catchment hydrology. (Figure 1).

The achievement of water equity for both humans and the environment in the Kouebokkeveld catchment can be possible through quantitative measurement of all factors impacting the hydrology of the catchment. SWAT+ hydrological model was set up to quantitatively reflect the conceptual knowledge of the hydrological processes and the effects of water abstraction and diversion, as illustrated in Figures 1. This model was selected for its flexibility in representing hydrological structures with extensive spatial distribution, crop growth, irrigation and land use management scenarios. Figure 2 shows the research methodological framework.

This study is ongoing. It is hoped that after final calibration, the modelled outputs will provide accurate insights into the actual catchment water balance of the KBV. The outcomes of this project will be used to support decision-making regarding sustainable water management. This includes being used as input into an Agent-Based Model (ABM) that will be utilised to explore various management scenarios (Figure 2). Furthermore, the modelled current and future water availability information will assist catchment managers in making informed decisions about how water management could be adapted to changes in water availability.

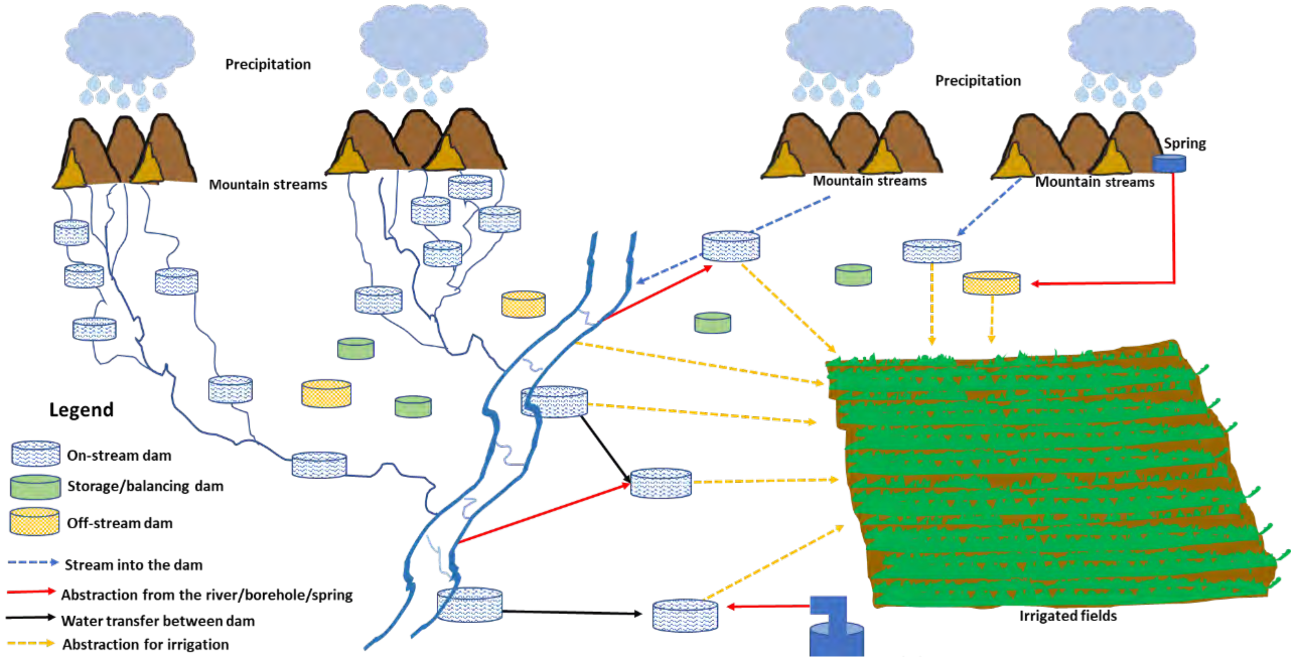


Figure 1: Conceptualisation of hydrological structures and water use and movement in the catchment

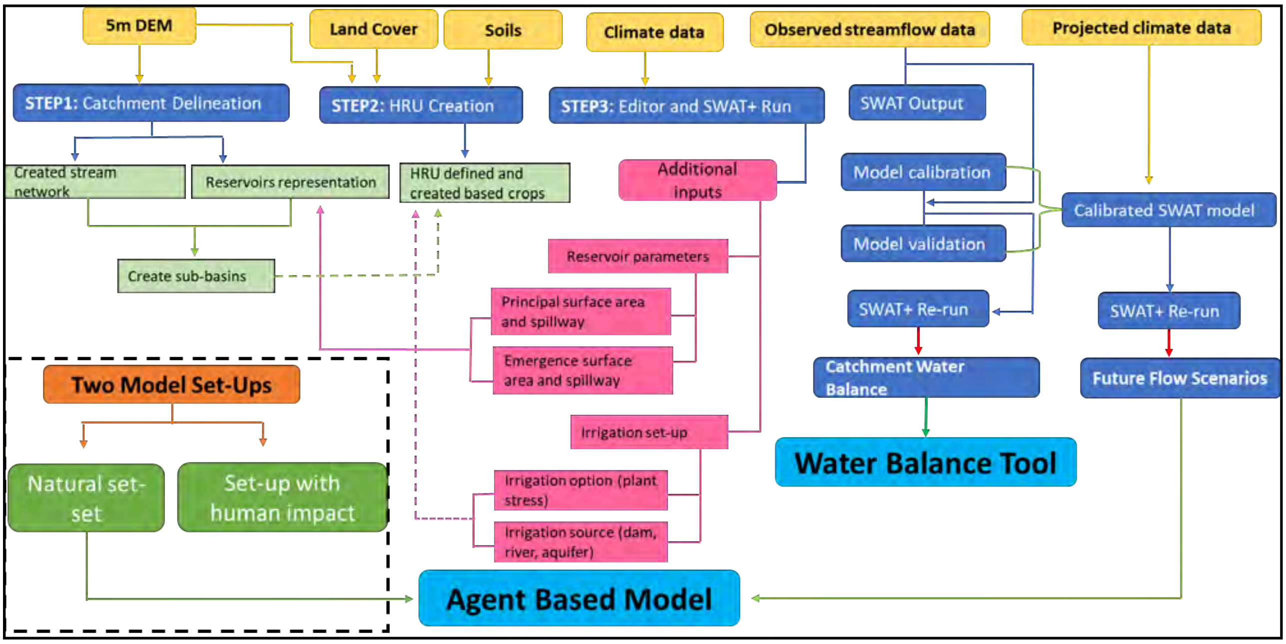


Figure 2: Methodological framework

Integration of satellite data to reduce hydrological modelling uncertainty for sustainable water resources management in Sub-saharan Africa

Student: HA Okal
Supervisors: JL Tanner and SK Mantel
Degree: PhD (Hydrology)

Brief overview

Data scarcity and information uncertainty threatens the reliable assessment of water resources in Sub-Saharan Africa (SSA). Hydro-climatic and hydro-meteorological networks are limited and poorly monitored, and water use information is unreported. Consequently, highly uncertain model outputs are used in assessments, planning, decision-making and management of water resources in SSA, leading to environmental and socio-economic risks, as well as lack of trust in modelling.

Substantial evidence shows many hydrological modelling studies within SSA are conducted by non-Africans. The resultant limited local expertise fostered in data generation, development and setups of global and regional models, and interpretation of outputs is a threat to achieving sustainable hydrological monitoring and assessment.

Outputs from global models are increasingly being used for water resource development and management decision-making. This could be attributed to local hydrological models having huge computation burdens as a result of numerous parameters and data requirements as opposed to global hydrological models (GHMs). However, studies show that global hydrological model outputs are not being sufficiently validated and are therefore unreliable. Additionally, the success of the outputs from GHMs is still debatable. Therefore, how well do outputs from GHMs perform vis-à-vis SSA's locally observed hydrological datasets?

Study aim and specific objectives

The aim is to compare and validate outputs from global hydrological models against local hydrological data in Sub-Saharan Africa, with specific objectives being:

1. To identify regions in SSA where information exists and where local capacity was involved in information-gathering and the modelling process;
2. To use outputs from local modelling studies to validate outputs from global hydrological models.

A systematic literature review for Objective (i) was conducted on hydrological modelling studies from 2000–2022 within SSA's 12 major river basins: Congo, Nile, Ganaane, and Rufiji representing the Eastern and Central SSA (SSA_{EC}); Senegal, Lake Chad, Volta, and Niger for the Western SSA (SSA_W); and Limpopo, Okavango, Orange, and Zambezi representing the Southern SSA (SSA_S). The same concept was adopted for Objective (ii) where studies that compared and validated GHMs within the SSA were reviewed.

The results revealed that only 11 of the 71 studies within SSA_{EC}, 9 of the 78 in SSA_W, and 10 of the 56 in SSA_S used *in situ* data for modelling. In addition, the lack of local capacity is highlighted as 46 of the 71 studies in the SSA_{EC}, 55 of the 78 in the SSA_W, and 27 of the 56 in the SSA_S showed no African institution was involved during the modelling and monitoring processes, and hence there was low local capacity strengthening (Figure 1).

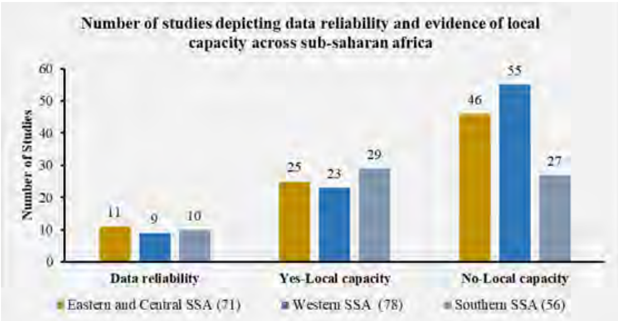


Figure 1: Graphical representation of data reliability and evidence of local capacity built from hydrological modelling studies across Sub-Saharan Africa

Most case studies showed that GHMs performed poorly in simulations. For example, Hughes and Tanner's (2018), CatchX Data Testing Report revealed that all seven Earth2Observe GHMs performed poorly against South Africa's WR2012 local datasets in most of the catchments in South Africa. Siderius et al. (2018) assessed the performance of unmodified Lund-Potsdam-Jena managed Land (LPJmL4) GHM in Rufiji and revealed that the model provided reasonable approximations of spatial variability and thus can be regionalised.

Conclusion

Data scarcity and low levels of local capacity development within the hydrological community in SSA pose threats to sustainable water resource assessment and management. Additionally, GHMs and global datasets need to be validated and proven to be reliable. Until they are, they should be considered imperfect, and warnings should be issued in all scientific publications associated with them.

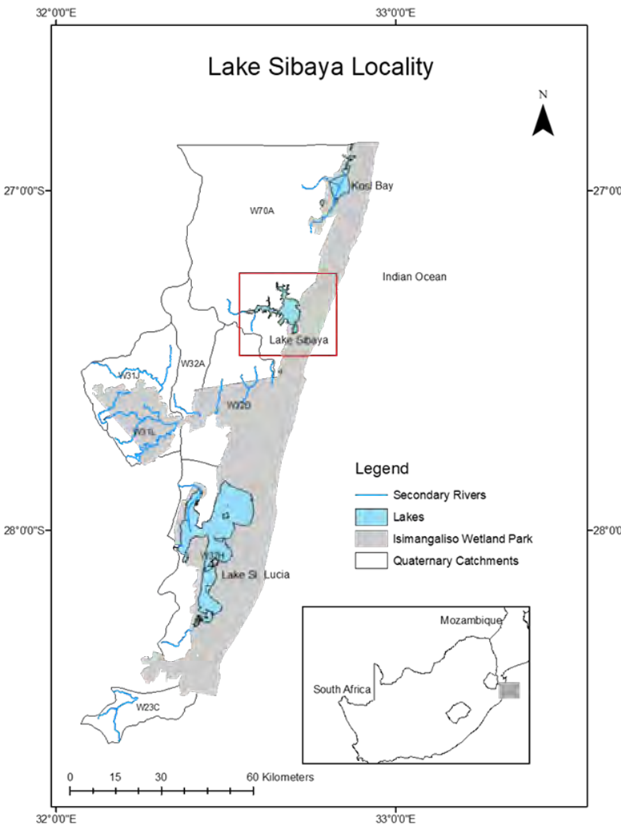
Finally, regional agencies are encouraged to build local capacity in the hydrological modelling field for improved expertise for a wise and sustainable hydrological modelling community.

Modelling and assessment of surface water-groundwater interactions in the Lake Sibaya catchment, South Africa

Student: Phatsimo Ramatsabana
Supervisor: J Tanner
Degree: MSc (Hydrology)

Surface water (SW) resources in South Africa are limited; more than 60% of the major rivers have experienced significant declines (Department of Water Affairs (DWA), 2013). As a result, groundwater (GW) is increasingly relied on (Braune et al., 2014; Department Water and Sanitation (DWS), 2016). Expanded utilization of GW highlights the need for careful management, bearing in mind that aquifers, too, have finite storage (Braune et al., 2014). Understanding and quantifying interactions between SW and GW is essential for the sustainable management of both resources (Rassam et al., 2013; Conant et al., 2019). Describing either of the components as a residual of the other ignores the crucial importance of interactions, with the consequence of highly uncertain water resource estimations (Parsons, 2004; Conant et al., 2019). Integrated hydrological models simulate the combined SW-GW system as a continuum and thus can appropriately support integrated water assessments (Tanner and Hughes, 2015; Li et al., 2016).

Considering the high heterogeneity and widespread occurrence of complex fractured rock environments in South Africa, it is preferable to utilise physically based models which are best suited to capture these heterogeneities more explicitly (Mul et al., 2009). However, the lack of adequate data frequently restricts the use of the more complex process-based models in favour of relatively simpler conceptual approaches (Hughes, 2013). Models with simpler structures have the benefit of fewer data requirements, but are limited in their capacity to reflect the full complexity of hydrological processes (Mul et al., 2009). For this study, the modified Pitman model (Hughes, 2004; 2013) was selected to assess how well a moderately detailed conceptual model can characterise SW-GW interactions. The key questions for successfully applying the Pitman model are whether processes can be adequately represented at broad spatial scales, and whether a robust conceptual understanding can help to reduce some of the uncertainties associated with parameter estimations within the context of a highly data-scarce region.



Locality map showing the location of Lake Sibaya within the iSimangaliso Wetland Park boundary (WR2012)

The model was set up for the Lake Sibaya catchment, which is a predominantly groundwater-driven system, and thus provides an important opportunity to interrogate different aspects of uncertainty in both the conceptualizing and quantifying interaction processes. Lake Sibaya is mainly recognised as one of the several lakes, swamps and lagoons that fall within the iSimangaliso Wetland

Park, a UNESCO World Heritage Site (Obura et al., 2012) (Figure 1). Recent activities, such as the establishment and expansion of plantations around the lake, have increased the demands on this ecologically sensitive area with a significant impact on lake levels (Weitz & Demlie, 2014; Smithers, 2017). On account of its conservation significance and position as a critical source of water for rural and urban supply, the continuing trend of declining lake levels in Lake Sibaya has prompted considerable research interest focused on various aspects of the lake, including the groundwater component.

The study's overall conclusion is that the model performed satisfactorily as it was able to simulate the lake's water balance correctly enough such that the influences of dominating components were sensibly reflected in variations in streamflow and lake volumes. The following key findings were noted: (i) the lake volume shows a continuous decline; (ii) the lake volume decreased with increasing development (forestry and abstractions) in the lake catchment; (iii) there is significant rainfall uncertainty in the study area, and the model showed high sensitivity to rainfall differences; (iv) robust conceptual knowledge of local catchment conditions was valuable for reducing some of the data-related uncertainty in the study area and for producing realistic model simulations; (v) the updated GW components can provide a useful tool for modelling integrated hydrological processes; nevertheless, when applying the model to specific environments, implicit approaches may be necessary to account for processes that are not fully represented in the model.

Application of the modified Pitman and SWAT models for groundwater recharge estimation in the upstream of the Uitenhage Artesian Basin, South Africa

Student: P Wasswa
Supervisor: JL Tanner
Degree: MSc (Hydrology)

Introduction

Globally, groundwater recharge is a central indicator and a critical hydrological variable in the provision of renewable freshwater resources for humans and ecosystems. Since the Renaissance, groundwater recharge has remained one of the most difficult hydrological variables to measure accurately, particularly in semi-arid and arid environments because of spatial variability in soil characteristics, topography, vegetation, land use/cover, and time variability of precipitation which make groundwater recharge fluxes generally low in comparison to received precipitation.

The Uitenhage Artesian Basin (UAB) (Figure 1) is South Africa's largest and most important groundwater artesian basin supplying groundwater in the Uitenhage area for various uses. Although the basin has been locally well researched in terms of hydrogeological characteristics, an insufficient understanding remains of upstream groundwater recharge dynamics which are dominated by Table Mountain Group Sandstones (TMGS). Understanding the dynamics of the upstream TMG recharge zone is key in assessing the longer-term impacts of the extensive groundwater use in the downstream artesian area of the basin. This study is targeted to fill this void by applying holistic approaches used by various authors to estimate and understand groundwater recharge dynamics in the upstream of the UAB, using knowledge from previous researchers in the study area, in combination with two hydrological models (Modified Pitman and SWAT) and other published information.

Tentative results

All the models (conceptual-perceptual, Pitman, and SWAT) (Figure 2), estimated the percentage of surface runoff and evapotranspiration to total mean annual precipitation (MAP) equally well, although significant variations in groundwater recharge were observed, with the conceptual-perceptual model predicting higher mean annual percentage recharge than the Modified Pitman and SWAT models. This difference can be accounted for in this study because, using a broad brush approach, the total change in storage was referred to as groundwater recharge.

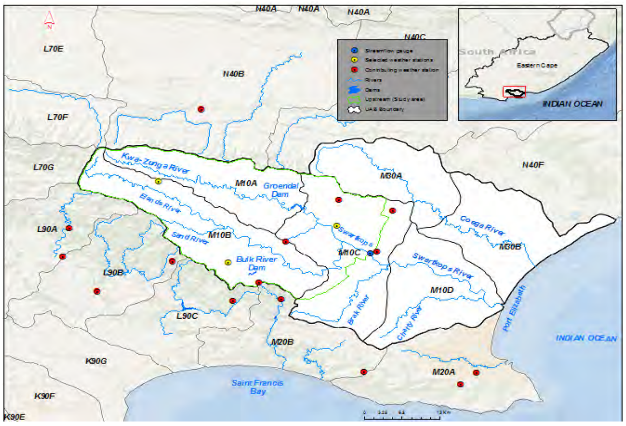


Figure 1. Map of the study area

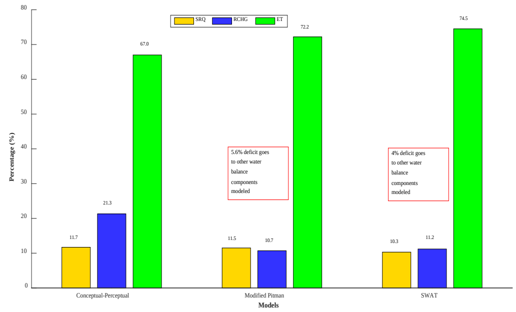


Figure 2. Comparison of model performance in estimating selected water balance components. (SRQ-Surface runoff; RCHG-Groundwater recharge; ET-Evapotranspiration)

Exploring the role of a water-use decision-support framework in reducing water risk uncertainty and improve decision-making

Student: BS Xoxo
Supervisors: JL Tanner, SK Mantel, and D Hughes
Degree: PhD (Hydrology)

About the PhD project

Recognising the ongoing decline of hydroclimatic data sources and the associated impacts on decision-support systems (Hughes, 2019), the Institute for Water Research developed a relatively simple Water Sharing Model that can handle uncertain input data and can be set up with water users to aid water use decision-making (Pienaar & Hughes, 2017). The main aim of this project is to test the value of an IWR-developed water allocation model, which takes uncertainty and vulnerability to water deficit into account to achieve fairness to all water users and future generations. To arrive at this aim, the project has the following sub-objectives:

- Develop a data collection (socio-economic data) protocol to facilitate the design of stakeholder engagement activities that elicit the correct type of information from the stakeholders for import into the model;
- Set up the model with stakeholders in the Koue Bokkeveld region (upper Doring catchment);
- Evaluate the model's usefulness as a decision-support framework under uncertainty for water use.

Figure 1: Sinetemba Xoxo (blue shirt), David Gwapedza (white shirt), Rodney Tholanah, playing the Dukunu Mole game (originally developed for a conservation intervention in Sao Tome Island) during the ComMod Invitational workshop in Montpellier, France, alongside other attendees from Switzerland, France, Brazil, Indonesia etc.

Given its participatory nature and the types of outcomes generated (Figure 1; Pienaar & Hughes, 2017), this project is envisioned as contributing theoretical and practical knowledge, and practical tools that can support data-driven decision-making in water scarcity hotspots.

Conflict reduction in fragmented social systems, when fragmentation is fuelled by conflict over water supply, is another potential consequence of the study, given its architecture (i.e., simulation and modelling-based and water user centred). In the end, the data and knowledge from this project can be used to strengthen the capacity of South

African catchment management to better confront hydrological uncertainty and make informed decisions at user level. The capacity to make decisions under uncertainty is necessary to cope with anticipated climate extremes, whose exact future dynamics and consequences are not known, but can be buffered through preparation. The local setting of this study is designed to better capture individual to economic-sector levels of knowledge to subsequently help in building a collective response, which would be difficult to achieve at macro scales.

Methodological improvements for how the policy scenarios (Figure 1) can be better evaluated during a stakeholder engagement workshop emerged from understanding the Companion Modelling (ComMod) Process. The ComMod process is a participatory approach that uses evolutionary models as mediation tools for discussion, shared learning, and group decision-making. The ComMod training was received during an invitational training workshop of the Companion Modelling approach, in Montpellier, France (May 2022).

The potential contribution of this tool towards fairness (i.e., social equity, economic efficiency, and ecological sustainability – the three pillars of the National Water Act of 1998) was presented in May 2022 during the 11th Assembly of the International Association for Hydrological Science, in Montpellier, France (Xoxo et al., 2022).

Procedure and outcomes of community weights (priority for supply) were presented in the conference "Crossing Borders of Knowledge", Rhodes University 2022, which was hosted by the Rhodes University Centre for Postgraduate Studies.

Water use of *Cannabis Sativa* in the Eastern Cape

Student: KTS Zenani
Supervisor: K Smart, A Palmer and J Tanner
Degree: MSc

Cannabis sativa, a temperate and herbaceous plant belonging to the Cannabaceae family, originated in the Eocene geological period. Evidence suggests that it has its roots in the present-day continent of Asia. Cannabis is separated into two distinct species: *Cannabis sativa,* found in central Asia, and *Cannabis indica,* found in the Indian subcontinent. Cultivation of this, one of the oldest plants, started approximately 3000 years ago in Asia, and over the centuries, it spread to all human-inhabited continents. The 20th century ushered in a new era in the history of cannabis, an era of criminalization of the plant. This criminalization was led by Western countries like the United States and many other countries followed suit soon after. The 21st century has seen an increased interest in the plant due to its many uses, ranging from medicinal, industrial, recreational etc., but its long-standing illegal status has created a dearth of knowledge concerning the plant. Many countries are trying to rectify this lack of knowledge by funding research in the cannabis field of study.

South Africa intends to rectify this ignorance about the plant. Following the relaxation of laws by government concerning the crop and increased interest in its cultivation in South Africa, the Water Research Commission has funded a project to investigate the water use of *Cannabis sativa* in order to determine the amount of water used by the plant. For the government to issue water-use licences, it is imperative that the amount of water the plant uses from a catchment area is known. Our study seeks to shed light on this matter by measuring evapotranspiration using a Large Aperture Scintillometer (LAS) and a hand-held leaf porometer. The data obtained will be used to model the total amount of water used by *C. sativa*. This study will use very few inputs in order simulate the conditions of a small-scale farmer in the rural Eastern Cape.

Field progress report

The first phase involved setting up an electric fence, the LAS, a weather station, and an irrigation system, followed shortly by discing the topsoil in order to remove grass, other small forbs and shrubs. Next, about 1000 seedlings were germinated, hardened for approximately 30 days and transplanted to the fenced cropping area. Once the seedlings were between 30 and 40 cm, they were transferred to the cropping area. The plants were irrigated once a day for 3 hours using the installed drip irrigation system, usually when soil moisture was below 22%.

The second phase was the collection of data from the Cannabis facility at Kenton-on-Sea at the beginning of June. The data included stomatal conductance, which was collected using a leaf porometer, photosynthetically active radiation, and leaf area index using a ceptometer. We also collected height and width of the plants during the growing cycle.

The third phase began in early September with the germination of about 1500 seeds. The difference between this and the first phase was the growing mixture used in Phase Three. This mixture contains powder growing, which proved to have a very high rate of success at the Cannabis facility in Kenton. The cropping area has been cleared and only needs to be disced again. In early November the crops will be moved to the cropping field where they will be monitored, irrigated and data will be collected.

Figure 1: Cleared cropping area at Firglen farm

Figure 2: Germinating seedlings on a tray at Firglen farm

Environmental Water Quality projects

Contributions of an ethically-grounded and values-based approach to water governance – the case of two contrasting catchments

ON Odume

April 2019 – March 2022

Sponsor: Water Research Commission
Collaborators: U Okeja (Department of Philosophy, Rhodes University)

The governance of water resources in the context of social-ecological systems (SES) is complex. This project develops an ethical and values-based approach to distil ethical criteria and principles for navigating the complexity of water governance as well as reflecting and analysing values, including value interactions. Using the Lower Sundays River catchment and the lower section of the Upper Vaal River catchment as case studies, this project develops an ethical and values-based approach to water governance in South Africa. The intention is to bring ethics and values-based analysis into the domain of water governance, and to shed light on its contribution to realising the foundational values of equity, sustainability and efficiency enshrined in the National Water Act.

Project aims

The specific aims of the project are as follows:

1. Together with stakeholders, surface key values informing water governance in the selected catchments and undertake a values-based analysis of how the stakeholders go about reconciling/trading off conflicting values, and the ethical implications.
2. Explore whether an appeal to ethics-level, context-sensitive principles can foster greater equity, sustainability, and efficiency in water governance in the selected catchments.
3. Explore instances of polycentricity in water governance in the catchments, paying attention to whether or not, in such instances, it contributes to effective and cooperative water governance.
4. Synthesise lessons of the value of an ethically grounded and values-based approach for policy, practice, and implementation, while providing comparative data from the selected catchments.

Project approach and methodology

The project uses a case study approach to generate insights and to synthesise knowledge on the contribution of an ethically grounded and values-based approach to water governance. Both secondary and primary data were collected through document analysis, workshops, interviews, surveys and focus group discussions.

Project results and discussion

We developed perspectives on water governance challenges and their ethical dimensions as well as an analysis of key values underlying water claims and claimants in the catchments. Regarding water governance challenges in the two catchments, we identified six challenges:

1. Effective participation, institutional legacies, and transformational challenges;
2. Accountability, cooperative governance, clear roles and responsibilities;
3. Absence/near absence of effective leadership and management;
4. Systemic integration failure of the water-land-agriculture (food) nexus, including institutional integration;
5. The regulatory system and failure of implementation;
6. Financing, infrastructure and technical capacity.

We reflected on the ethical dimensions of these challenges. For example, regarding Challenge 1, we reasoned that serious ethical concerns exist about perpetuating power differentials on access to water resources within the Lower Sundays River catchment, thus raising issues of distributive justice. For instance, the National Water Act provides that members of the Irrigation Board shall automatically become members of Water Users Association (WUA), inadvertently giving such members powers to set out the constitution, and define the functions of the WUA within the ambit of the law. This raises serious ethical challenges as historically powerful interests within Irrigation Boards retain enormous, disproportionate influence over the agenda and trajectory of the Lower Sundays River Water Users Association (LSRWUA).

Building on the perspectives on water governance challenges and their ethical dimensions, we identified efficiency, sustainability, equity, diversity, and inclusivity, transparency, accountability, and social and ecological justice as the key values underpinning water governance in the catchments. We draw on the theories of ethics to reflect on and reason about value claims. In this regard, we reason about values and morals from the perspectives of consequentialism, deontology, virtue ethics, Ubuntu moral theory and systemic-relational perspectives. By applying thinking from these fields of ethical theories, we were able to clarify value claims about water in the catchment. For example, in both catchments, the governance institutions seemed to emphasise efficiency and are thus consequentialist in moral outlook and in design. By drawing on the theories of ethics, we lay the foundation for clarifying value claims to water in the catchments, but the perspectives developed in this study can be applied elsewhere.

To address the question on how to achieve greater equity, sustainability and efficiency, we develop a framework for analysing value interaction in water governance, and factors that may impact on such interactions. We identified three dynamic zones of value interactions: i) the conflictual zone, ii) the mutually enhancing zone, and iii) the neutral zone. We reasoned that greater equity, sustainability and efficiency are better achieved in the mutually enhancing zone. Within this zone, the achievement of one of the values contributes to achieving the remaining two values. However, our empirical assessments suggest that in both catchments, the conflictual zone dynamic dominates. What this means is that the three values of equity, efficiency and sustainability are often in conflict in practical and policy senses, in such a way that practical and policy steps taken to achieve one value constrain the achievement of the other values. We identified better understanding, appreciation and the role of i) context, ii) governance, iii) time-frame dependence iv) spatial-scale dependence v) agent and capability, and vi) resources and investment, as fundamental to shifting current realities away from the conflictual zone interaction to the desired, mutually enhancing zone of value interaction.

There are fundamental practical and policy implications in this regard. For example, a deeper appreciation of the true meaning of the values of equity, efficiency, and sustainability is needed. In the practical and policy sense, equity needs to be better understood as a multi-dimensional concept involving procedural equity, distributive equity, contextual equity and recognitional equity. Short-sighted policy measures may focus on the distributive dimension, but this may not lead to a holistic achievement of the practical implications of equity. In the same sense, efficiency, as we demonstrated, is also multi-dimensional, so is sustainability, which has ecological justice implications.

We consider whether polycentricity as a governance approach can contribute to effective cooperative governance in the two catchments. Drawing on the key characteristics of polycentricity, we develop an analytical assessment grid to determine the degree of polycentricity in the two catchments. Based on the assessment grid, the degree of polycentricity can be characterised as i) matured polycentricity, ii) x-emerging polycentricity, iii) y-emerging polycentricity and iv) budding polycentricity. We characterise matured polycentricity as instances where a multiplicity of autonomous or largely autonomous units exists, governing a resource in a manner that shows effective coordination, displaying interdependence, and varying intensity and frequency of interactions within a defined set of rules. We define the y-emerging polycentricity as a situation where few governance units are responsible for key governance processes and decision making but have a high degree of coordination and interactions between these units, showing high levels of interrelations and interdependence. The x-emerging polycentricity exemplifies a situation whereby a diversity of largely autonomous units is responsible for and participates in the governance processes, but shows low coordination ability and thus a low level of interrelation and interdependence. The fourth degree of polycentricity is what we have termed 'budding polycentricity', typifying a situation where poor coordination and interrelations exist between the few governance units operating within a catchment.

The empirical evidence in the two catchments suggests that neither has a matured polycentric governance approach, raising implications around the degree of adaptive capacity of the operating governance approaches in the two catchments. We reasoned that, given the complexity of achieving equity, efficiency and sustainability, a high degree of adaptive capacity offered by a polycentric governance approach is desirable. The level of polycentricity in the two catchments then raises serious policy and implementation questions regarding institutional design and operationalisation in the catchments and, by extension, in the country. The degree of polycentricity in the two catchments raises concern as to the alignment between institutional fit and social-ecological realities. An alignment is needed to achieve greater equity, efficiency, and sustainability as factors impacting on these values operate across social-ecological scales.

Another governance implication that is raised in the catchment in terms of degree of polycentricity is whether there is enough room for learning and experimentation, and whether the current institutional and governance processes benefit from a diversity of knowledge sources and knowledge-sharing across scales. For instance, diversity of knowledge sources and knowledge-sharing imply participation by diverse stakeholders across jurisdictional scales in decision making. Such participation gives effect to procedural equity, which may, in turn, accelerate distributive equity imperatives through representation and participation of diverse interest groups, particularly those who have been historically marginalised. We reasoned that the degree of polycentricity in the two catchments may have contributed to the observation that equity imperatives are often in conflict with those of efficiency. Part of the reason for this is that experimentation and knowledge-sharing from diverse sources are critical to realising equity goals, yet current institutional design operating in the two catchments may not give sufficient room for such experimentation and knowledge-sharing across scales and from diverse sources.

Recommendations

Policy and implementation

1. This study raises fundamental practical and policy issues. First, there is a need for a deeper appreciation and understanding of the true meaning of the values of equity, efficiency, and sustainability. As we have demonstrated, these values are complex and multi-dimensional, and relevant policies in the water sector need to appreciate these complexities and multi-dimensionality. For example, in policy matters, equity needs to be positioned in a multi-dimensional sense as including procedural equity, distributive equity, contextual equity and recognitional equity. This also applies to the multi-dimensionality of sustainability and efficiency. There is a need for a balanced focus on all dimensions of these interlinked values, avoiding short-sighted policy measures that may focus on just one dimension, for example, distributive equity or technical efficiency.
2. Long-term policy instruments are needed to better appreciate how the three values may interact, the context in which such interaction comes into play, and the factors that may contribute to whether the interactions are conflictual or mutually enhancing. Specifically, policy instruments need to make explicit that the pursuit of equity in the water sector is a long-term gaol. In this regard, indicators for monitoring equity progress in the short-, medium-, and long-term also need to be developed and implemented in specific contexts. Policy guidance also needs to be given on how the pursuit of the values of equity, efficiency and sustainability may interact in the short-, medium-, and long-term, and what needs to be done to shift these interactions away from conflictual to mutually enhancing. This would require a good understanding of time-frame dependence and spatial-scale dependence on the interactions between these values.
3. The concurrent achievement of equity, efficiency and sustainability in the water sector is a complex exercise impacted upon by several factors. In this regard, policy guidance is needed on how a specific context in the water sector may influence the achievement of these values. Good governance also needs to be strengthened. A clear policy intent and implementation mechanisms need to be mapped on strengthening capabilities in the water sector and on setting aside resources for investing into equity, sustainability, and efficiency imperatives over the short-, medium-, and long-term.
4. There is an urgent need for institutional reformation and re-design in the water sector, as exemplified in the two catchments, to enhance their fit to local social-ecological realities and to enhance their adaptive capacity, promote participation and experimentation, learning, knowledge-sharing from diverse sources and systems. For example, in the case of the Water Users Associations (WUAs), urgent reform is needed to redesign these institutions so that historical institutional legacies that impede transformation and effective participation, and bolster power differentials are not perpetuated. At the time of writing, this task has been taken up by the Department of Water and Sanitation; urgent finalisation of this process is needed.
5. Training of policy makers, managers and water sector stakeholders is required across institutional and governance scales on how ethical thinking may contribute to clarifying value claims in the water sector, and its role in water diplomacy and dispute resolution. This is necessary because much of the conflict around water is indeed values-based conflict.

Further research

The following recommendations are made for future studies

1. Examine and analyse the extent to which current institutional designs and governance processes in the water sector contribute to the conflictual interactions between the value of equity, sustainability, and efficiency. Such an examination is essential to distil the important institutional elements necessary for shifting current realities away from conflictual value interaction zone dynamics to the mutually enhancing value interaction zone dynamics.

2. Undertake a case-study-based approach to develop indicators that draw on the multi-dimensionality of equity, efficiency, and sustainability and to use the developed indicators to monitor the effectiveness of the implementation mechanisms for the values of equity, efficiency, and sustainability. Such a study should also distil the role of agency and capability on the values of equity, efficiency, and sustainability in specific contexts.
3. The present study has developed several analytical frameworks: i) that of value interactions, ii) ethical theories for reflecting on value claims, iii) an analytical grid for assessing the degree of polycentricity, and iv) for reflecting on ethical dimensions of water governance challenges. Future studies that apply these frameworks in comparative case studies are needed to validate these frameworks and to further distil lessons on the role of ethics in water governance for policy and implementation.

African Water Resources Mobility Network (AWaRMN): building transdisciplinary capacity for sustainable water resources management in Africa

ON Odume and CF Nnadozie

January 2020–December 2024

Sponsor: Intra-Africa Academic Mobility Scheme of the European Union
Collaborators: Federal University of Technology, Minna, Nigeria; University of Kinshasa, DRC; Makerere University, Uganda; National Higher School of Hydraulics, Algeria; TU Delft, Netherlands

Project website for additional details
https://www.ru.ac.za/intra-africa-awarmn/

This multi-partner EU-funded project aims to develop African capacity for sustainable water resources management through the Intra-Africa Academic Mobility. This objective is founded on the realisation that achieving sustainable development and inclusive growth within Africa would largely be undermined if its water resources are not sustainably managed, utilised, protected and governed by competent and qualified professionals. The continent is facing multiple water-related challenges that include declining water quantity and quality, inadequate governance and institutional structures, declining monitoring networks, increasing resource use in the face of a growing human population, and increasing resource variability associated with future changing climates. As the region strives toward improving political, economic and social stability, the importance of secure water supplies will assume increasing significance. If this is neglected, the potential for conflict exists: 1) within and between communities through a lack of water- and sanitation-related access and services, 2) between countries through a lack of agreement on transboundary sharing of water resources, and most importantly, 3) between societal constituencies through perceived non-inclusive and equitable sharing of water resources (distributive justice).

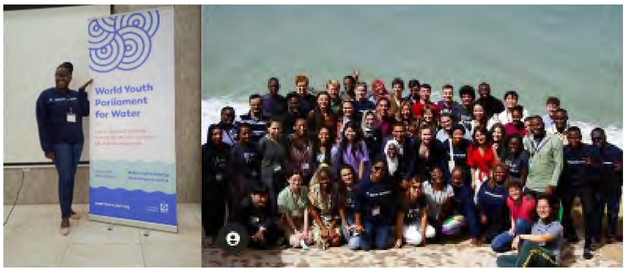
The AWaRMN project currently supports 34 MSc and PhD students from more than 15 African countries. These students are registered in partner universities, pursuing their Masters' and Doctorates in the field of water and related disciplines. Of the 34 students currently supported by the project, four have completed their mobilities, and several have participated in local and international training opportunities, conferences and workshops. Overall, the AWaRMN project has proved very successful to date in delivering its mandate of strengthening capacity and facilitating intra-Africa academic mobility.

AWaRMN scholars and Afro-Innovators who participated in the 5th edition of the W4F Hackathon organised by the UNESCO ICIREWARD International Centre in Montpellier, France (right).

AWaRMN scholar, Ms Mariam Usman celebrates her graduation at Makerere University

AWaRMN scholar Mr Gilbert presenting a paper at 15th Conference of Zoological Society of Nigeria (ZSN)

Ms Kopa Imerina receiving an award at the 1st International Conference on Sustainable Soil Management: Challenge for Food Security (ICSSM-2022) organised by the Centre for Science and Technology in Dry Regions (CRSTRA)



AWaRMN scholar, Ms Harriett Okal, attended the World Youth Parliament

Ms Mary Chibwe (third from right) attended a Science Communication Training Workshop.

AWARMN is funded by the Intra-Africa Academic Mobility Scheme of the European Union https://eacea.ec.europa.eu/intra-africa_en

Microplastics as emerging contaminants: method development, ecotoxicity testing and biomonitoring in South African water resources

N Mgaba, ON Odume, PK Mensah and N Griffin
April 2019–March 2022

Sponsor: Water Research Commission

Increases in the production of plastic materials globally have led to their ubiquity in the environment. To date, plastics of all sizes have been reported in all type of environments: marine, freshwater, terrestrial, agricultural lands, drinking water, and air. The ubiquity of plastic materials within the environment, coupled with the fact that they are not easily degradable, has raised serious concerns about the ecological and human health risk they pose. Current empirical evidence suggests that the ecological and human health risk posed by plastics is influenced by several factors: the physical and chemical properties of the plastic material, the vulnerability of the impacted biological agent, and the concentration and distribution of plastics in the environment.

In South Africa, microplastics have reportedly occurred in river systems, but not much work has been done to examine the potential toxicity and effects of microplastics on biological systems at environmentally realistic concentrations. To this end, methods for quantifying the effects of microplastic or their toxicity have not been well established, although standard toxicity testing methods could be adapted. This project thus fills an important knowledge gap by investigating the occurrence and distribution of microplastics in the Swartkops and Buffalo River systems in the Eastern Cape, as well as the ecotoxicity of microplastics and plasticisers on selected test organisms at environmentally realistic concentrations.

Project aims

The following are the specific aims of the project

1. To convene a project inception workshop and update a literature review on microplastics in freshwater environments based on national and international reports, focusing on ecotoxicity testing for human health and environmental risk assessment.
2. To develop (or adapt) methods for quantification and characterisation microplastics in freshwater systems, as well as methods for assessing the toxicity of microplastics (as chemical and

physical stressors) using selected test freshwater organisms through multiple life stages.

3. To evaluate the potential toxicity of microplastics as chemical stressors due to the presence of additives (e.g., plasticisers) based on novel endpoints using selected test organisms through multiple life stages.
4. To evaluate the potential toxicity of microplastics as physical stressors, considering different shapes and sizes of microplastic particles, based on novel endpoints using selected test organisms through multiple life stages.
5. To apply the developed (or adapted) toxicity-based methods for assessing the environmental risks of microplastics (as chemical and physical stressors) in selected South African river systems (Swartkops and Buffalo rivers) using selected test organisms, through multiple life stages.
6. To compile a communique and policy document on the toxicity of microplastics in the environment as well as recommendations for microplastics monitoring in freshwater ecosystems.

Project approach and methodology

An initial literature review, which focused on the reported effects of microplastics on freshwater organisms, from cellular to whole organism effects was conducted. Subsequently, laboratory studies were conducted, exposing different life stages of the freshwater snail (*Melanoides tuberculate*), shrimp (*Caridina nilotica*), zebra fish (*Danio rerio*), and tilapia fish (*Tilapia sparrmanii*) to different concentrations and types of microplastics, including polypropylene (PP) (0 – 6263 particles/L), polyethene (PE) (0 – 3691 particles/L) and polyvinyl chloride (PVC) (0 – 2880 particles/L). For PP, fibres constituted 30% of the particles, spheres 20%, and irregularly shaped particles constituted 50% of the test solution. For PE, 65% of the particles in solution were fibres, 15% were spheres and 20% were irregularly shaped. For the PVC, 20% of the particles were fibres, 30% spheres and 50% irregularly shaped. The average sizes of the particles used for the experiments were 18.4 µm for PP, 29.3 µm for PE and 24.8 µm for PVV. The size ranges were 1.7 – 1400 µm for PP, 10 – 2500 µm for PE, and 2.9 –1600 µm for PVC.

Various endpoints were tested, including biochemical effects, growth, and reproduction. Test organisms were also exposed to selected plasticisers, including Bisphenol A, Dibutyl Phthalate, and calcium stearate at environmentally realistic concentrations. *Melanoides tuberculate*, *Caridina nilotica*, *Danio rerio*, *Tilapia sparrmanii* were exposed to 0–0.00215 µg/l of dibutyl phthalate, 0–4 µg/l of Bisphenol A and 0–5 mg/l calcium stearate. To determine the presence and prevalence of microplastics in freshwater, water samples were periodically collected from the Swartkops and Buffalo rivers over one hydrological year, taking samples from distinct biotopes.

AWaRMN scholar, Mr Edgar Tumwesigye, removing plastic litter from rivers in Makhanda/Grahamstown.

Results and discussion

Current science of the effects of microplastics on environmental health

A review of current literature indicated that microplastic effects have been reported at the cellular, tissue and whole organism levels, but concentrations at which effects are observed are usually higher than those generally reported in the field. According to literature, cellular and biochemical effects observed are mostly related to changes in gene expression, effects on enzymatic activity and oxidative stress. At the tissue level, blockage of the gut, translocation of microplastic to the liver and abrasion of the gut are some of the typical effects reported. Whole organism effects are mainly behavioural and relate mostly to feeding behaviour. Observed effects are mediated by the test organisms, concentrations of microplastics, shapes and sizes of microplastics, and exposure duration. With regard to human health, inhalation and ingestion via drinking water and food materials are the main exposure routes, in addition to high-risk occupations. In the literature, inflammatory responses and lesions, production of reactive oxygen species (ROS), and genotoxicity effects have been reported for humans.

Laboratory studies on the effects of microplastics on aquatic organisms

In terms of the laboratory experiments conducted in this study, significant effects due to exposure to microplastics were not observed for most of the test organisms at the test microplastic concentrations and particle sizes and shapes investigated. In the results obtained using the freshwater snail (*Melanoides tuberculate*), no significant effects were observed for adult snail reproduction and growth, nor did the juvenile snail exhibit any effects due to exposure to microplastics. However, the dose-response curve suggested that growth is slowed at higher concentrations in young snails to a greater extent than in adult snails. There were high variations in the data, and the fitted curve could not be said to show the polyvinyl chloride response significantly. No effects were observed on the growth of Tilapia at the test concentrations after 21 days of exposure. Thus, using the microplastics at the concentrations tested, no significant toxicological responses were observed, except for the effects of polypropylene particles on fish growth. However, it was observed that fish significantly egested consumed microplastics, through a process of gut clearing. It needs to be noted that even though no responses were found during the exposure tests, this does not rule out other potential impacts owing to, for example, long-term plastic accumulation in the gut and consequent feeding reduction, which were, however, not observed in the present study.

Laboratory studies on the effects of plasticisers on aquatic organisms

Apart from the effects of Bisphenol A on snail reproduction, minimal effects caused by exposure to plasticisers were observed for most of the test organisms investigated in this study. Bisphenol A had a profound effect on the reproduction of *M. tuberculate*, significantly decreasing the production of offspring and overall reproductive success at the test concentrations. The other plasticisers had no clear effect on snail reproductive success. This result indicates that plastics with Bisphenol A could pose a potential significant ecological risk in the environment if the plasticiser is leached. At higher concentrations of the plasticisers, often at concentrations higher than those reported in the environment, effects on the test organisms could be detected.

Monitoring the presence of microplastics in the Swartkops and Buffalo rivers

The results of the field study indicate widespread occurrence of microplastics, providing further empirical evidence for the claim of the ubiquity of microplastics in South African freshwater systems. This observation raises the question of what such high levels of microplastics might mean for river biota. In the microplastic toxicology exposures undertaken in this project, these field concentrations were relatively low, and in laboratory exposures, no toxic impact was detected on a range of endpoints. These results accord with international observations that microplastic exposures that elicit a biotic response are often at levels of microplastics far higher than are encountered in the environment. In a similar light, European scientific advisers concluded that no known risks were posed by environmental levels of microplastics. It is, therefore, possible that the physical effect of this level of microplastic particles on biota in the environment may be limited or undetectable.

Conclusion

The findings of this study suggest that, generally, plasticisers seem to impact on stress enzyme activity, though many other endpoints showed little response. Given the lack of significant response of most endpoints to the plasticisers in other tests, and the near absence of clear responses to physical exposure to microplastics, it is of value to identify one pathway that may lead to microplastic impacts in the environment. Importantly, the study has contributed to providing research-based tools that can be used to protect freshwater resources from microplastic pollution in South Africa. Techniques such as characterisation of microplastics and toxicity tests for microplastics using different aquatic organisms that are useful for investigating microplastic impacts in the aquatic environment have been explored as important outcomes of this project. As pointed out in the literature, most methods for microplastics research were developed for the marine environment. In this study, these methods were adapted, modified, and/or optimised to develop new methods to enhance their application for studying microplastics in freshwater ecosystems, with a focus on freshwater systems in South Africa. In view of this, methods for undertaking biomonitoring studies involving microplastics in freshwater systems and ecotoxicological studies using freshwater organisms have been developed as outcomes of this project.

Recommendations for policy and implementation

- Although the results of the present study seem to suggest that microplastics posed minimal ecological risk, at least to the biota tested at concentrations reported in the environment,

policy instruments should be directed towards minimising the entry of plastic materials into freshwater resources. Both punitive and incentive-based systems can be implemented to prevent and/or minimise plastic pollution of freshwater systems. Such policy instruments should consider the plastic value and production chains, as well as behavioural and technological drivers of change towards plastic reduction in the environment.
- Despite the empirical evidence suggesting the presence of microplastics in South African riverine systems, their occurrence and distribution as well as potential toxicity on indigenous species are poorly studied. A multi-disciplinary microplastic monitoring network and programme is recommended. Such a programme would seek to generate data on microplastics occurrence, geospatial distribution, use, toxicity, and human and ecological risk. Such data would be critical for evidence-based policy instruments in South Africa.
- Policy instruments should target both hard and soft measures, such as behavioural change, social learning, and technological innovations for the recycling, re-use, and reduction of plastic materials through the principles of a circular and green economy.

Recommendations for future research

The following are recommended for future studies

- An ecological functional approach to a toxicity study of microplastic is recommended. This could include an analysis of the effects of microplastics on feeding efficiency, feeding behaviour, oxygen uptake and metabolic function. It is likely that effects could be observed if a functional approach is followed.
- Microplastics occurrence and distribution in the riverine systems is potentially mediated by hydrology, hydraulic characteristics and microplastic movements (lateral, vertical, and horizontal). A mechanistic approach that seeks to understand the influences of hydrology and hydraulics on the distribution of microplastics, and thus, the potential exposure of riverine organisms, is recommended.

An ecosystem-based climate resilience approach to assure water security in the Amathole District Municipality, Eastern Cape, South Africa

ON Odume, CF Nnadozie, FC Akamagwuna

Nov 2021–September 2022

Sponsor: GIZ

South Africa is vulnerable to water-related shocks and crises such as climate change and the risk of zoonotic pandemic. In the Amathole District Municipality (ADM) for example, climate-induced change has manifested in the form of prolonged drought and extreme rainfall variability. As climate change continues to exert its influence on water resources and water-related services, the occurrences of zoonotic-induced pandemics are increasingly becoming a threat not only to ecosystems functionality, but also to water-related service delivery.

The combined effects of both climate change and zoonotic-induced pandemics can be devastating on the water sector, as exemplified by the COVID-19 pandemic and the climate-induced water crises in Cape Town, Nelson Mandela Bay Metro, and the ADM. Although climate change and zoonotic-induced pandemics can both be regarded as crises, the way in which they progress and manifest often affect institutional and governance responses, as well as risk perception. Though they both may progress at different a pace, and affect the water sector differently, what is needed are robust adaptive measures and mechanisms for enhancing resilience in the water sector.

An ecosystem-based approach to strengthening the water sector resilience to climate and zoonotic shocks and crises is critical because it links freshwater ecosystems to water and sanitation services, as well as their associated institutions and governance processes. Viewed from a social-ecological system and One Health perspectives, an ecosystem-based approach enables i) the identification of drivers and pressure on ecosystem structure, function, and processes; ii) the impact of pressure on ecosystem services and disservices flows; iii) the benefits and costs to society, and iv) internal and external leverage points for enhancing ecosystem resilience to assure water security, sanitation, and reduction of zoonosis.

Considering the above, the German Agency for International Cooperation (GIZ) provided a grant to Rhodes University via its Institute for Water Research, to identify multi-pronged, ecosystem-based measures to strengthen the water sector resilience to climate change and risk of zoonoses (pandemics) in the Amathole District Municipality (ADM) in the Eastern Cape, South Africa. This includes facilitating an ecosystem-based, strategic adaptive management (SAM) approach in the identification of the measures to reduce zoonotic risks, enhance ecosystem resilience to climate change and the risk of zoonotic crises, as well as mapping freshwater ecosystem threats and the risk of zoonoses in the ADM. This was a short-term, 10-month grant, with the intention of generating the knowledge necessary for enhancing water sector resilience to climate and future zoonotic risk within the ADM. This reports on the key outcomes of the SAM-APP process, the mapping of freshwater ecosystem threats, and zoonotic risk within the ADM.

Participatory mapping of ecosystem (dis)services with CMF members in Hogsback

The SAM process led to a draft collective vision for the catchment with inputs from diverse stakeholders:

> *A safe, healthy, catchment ecosystem providing enough clean water for people, animals, and livelihoods, managed sustainably and responsibly by government working together with local stakeholders.*

Key pressure identified through a participatory, engaged GIS mapping activity identified soil erosion, over-grazing, climate change, water scarcity, pollution of water sources and poor infrastructure maintenance. The burden arising from these ecosystem pressures is disproportionately felt by the most marginalised constituencies, who are also least able to adapt to the challenges posed by complex problems like climate change and zoonotic pandemics. The existing system of catchment management based on voluntary structures seems to further marginalise the voices and participation of the least powerful, and arguably most affected, actors within the system. Nevertheless, there was openness and an appetite for the adoption of ecosystem-based solutions within the catchment, with the added benefit that initiatives of this type (e.g., clearing alien vegetation, and land care management practices) have been implemented successfully in the past, and there is existing knowledge and experience to build upon. The Catchment Management Forum (CMF) is a critical asset in this regard as the necessary knowledge base, skills, networks, social capital, and experiences reside within the forum. However, strengthening the capability of the CMF, and exploring a viable financial sustainability model is critically important. Options explored with members of the CMFs, some of which are currently being considered, included group savings/microfinance models, registering as a public benefit organisation for tax incentives, monetising ecosystem services, for example, controlling erosion and grazing for commercial farmers for a fee, etc.

At a different level, larger-scale and emerging commercial farmers reported that they are already actively pursuing the use of new and more environmentally sustainable practices and technology, driven by the imperatives of limited water available for irrigation and the need to comply with export standards. At the level of subsistence livestock and crop farmers, training on best management practices would be welcomed as a short-term intervention, or as part of a broader implementation plan. A possible starting point might be trying to form a partnership between CMF and citrus farmers around areas of common concern (e.g., over-grazing and deforestation).

With regard to the biophysical threat to freshwater ecosystems, we took a biophysical mapping approach to identifying the potential risks to freshwater systems by combining estimates of the threat to aquatic ecosystems with vulnerability estimates of the ecosystem in question. Threats were identified from ADM water and sanitation infrastructure, roads networks, and land use patterns, and vulnerability was linked to National Freshwater Ecosystem Priority Areas (NFEPA) river class as well as Critical Biodiversity Areas. Impacts were predicted where threats and vulnerable areas coincided.

Risk as a result of ADM sanitation and water infrastructure was found to be fairly limited, and largely restricted to urban areas. Where towns were not built on watercourses, this risk was further minimised as risk to water resources alone was in consideration. However, it is important to note that private water sources (largely boreholes and associated piping) and sanitation systems (largely septic tanks or pit latrines) were not considered as these data were not available. Given the rural nature of the region, their potential contribution to waterborne risk may be significant.

Risks posed by the exposure of rivers to the road network covered the greatest area. However, the magnitude of this risk was low. In areas where roads followed rivers, exposure was high, and the risk of cumulative impact was present. Nevertheless, risk scores were low and the likelihood of significant risk owing to roads compared to sewage leaks and other threats that were assessed was low.

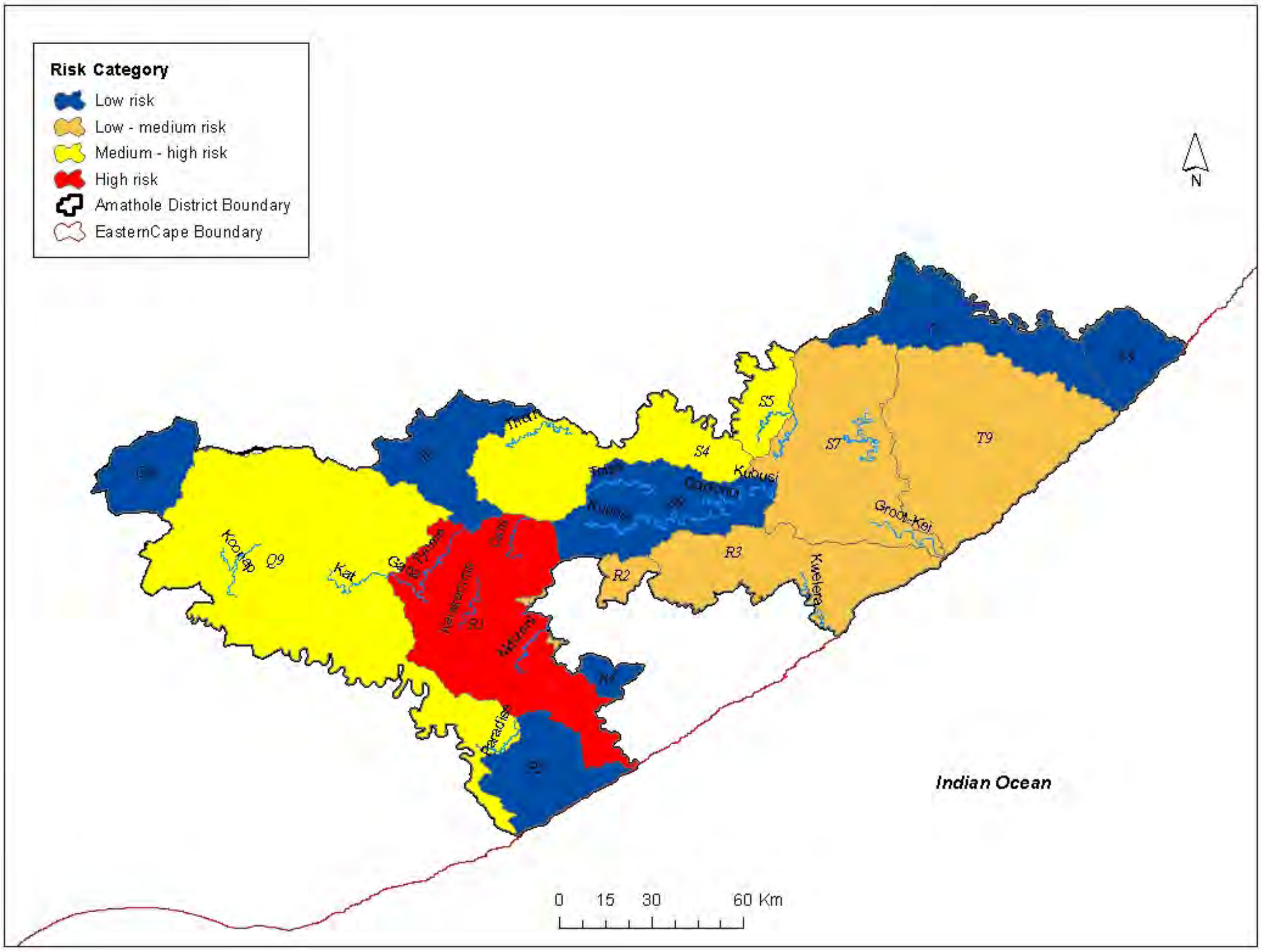
Land uses including industrial land, commercial land, eroded land, sewage treatment and disposal, roads, residential, erosion, and cultivated agriculture were identified as potential threats to freshwater systems. The potential threats to water quality cover a relatively small area, although the potential risk score was sometimes significant. That the area of land affected was small, regardless of the number of land classes associated with potential threats to freshwater integrity, illustrates the rural nature of the study area. Looking more closely at the data, many of the potential threats were related to cultivation of land near rivers, or use of that land for residential purposes.

Overall, the area was found to be largely rural, with relatively little risk to freshwater resources. Those risks that were found were mostly associated with urbanisation, or with cultivation of land along rivers. Although the size of towns in the area is limited, badly run wastewater treatment works can have a serious impact on freshwater health, and a recent survey of several towns found poorly scored wastewater treatment works. Owing to different land use practices, the extent of the impact of farming will vary.

Regarding zoonoses within the ADM, we identified key risk factors of zoonoses as wastewater treatment works (WWTWs), uncontrolled movement of livestock, hospital wastes, households with poor or no sanitation, wildlife, abattoirs, commercial farms, slurry-treated soils, use of swine waste, and flooding events. The identified zoonotic pathogens potentially circulating in water sources within the ADM include Hepatitis E virus, *Mycobacterium tuberculosis* complex, *Brucella* spp., *E coli* O157:H7, *Salmonella*, Group 1 *Rotavirus*, *Cryptosporidium*, *Fasciola hepatica* and *Fasciola gigantica*, and *Campylobacter* spp. Areas most at risk of zoonoses within the ADM included the south-eastern portion of the Raymond Mhlaba, the central, south-western parts of the Amahlathi municipality, and the northern part of the Ngqushwa municipality. Other areas at high risk of zoonotic emergence are the Great Kei region as well as southern part of the Mbashe local municipality. It is recommended that anticipatory governance be strengthened to minimise zoonoses risk in these parts of the ADM.

Key drivers and pressure identified by stakeholders in the Kat River Valley catchment within the ADM

Drivers and pressure	Severity	Trend	Time (Yrs)
Soil erosion / over- grazing	Very serious	Increase	20+
Climate change / Drought	Very serious	Increase	20+
Water scarcity / no running water in taps	Very serious	Increase	5–15
Dumping / Water pollution	Very serious	Increase	5–15
No infrastructure maintenance	Very serious	Increase	5–15
Stock theft	Very Serious	Increase	0–5
Human and natural causes	Very Serious	Increase	5–15
Decrease in aquatic life	Very Serious	Increase	5–15
Lack of fenced camps	Serious	Increase	0–5
Growth of alien plants	Low	Consistent	0–15
Community projects (*Positive driver)*	Significant	Increase	0–5



River sites with risk level in terms of their potential for the transmission of zoonotic pathogens within Amathole District municipality.

African urban complexities and the governance challenges of urban rivers – a systemic-relational inquiry

ON Odume, CF Nnadozie, FC Akamagwuna and DR Choruma

June 2021 - May 2023

Sponsor: University of Bayreuth – Africa Multiple Cluster of Excellence
Collaborators: Dr Blessing Nonye Onyima, Nnamdi Azikiwe University, Nigeria; Mr Omovoh, Gift, Federal Ministry of Environment, Nigeria; Prof. Uchenna Okeja, Department of Philosophy, Rhodes University

The trajectory of urbanisation in Africa is complex, presenting potentially intractable governance challenges of natural resources such as urban rivers. In Africa, urban river systems are often seriously degraded and recent empirical evidence suggests the accumulation of novel pollutants such as macro- and microplastics in such river systems (Grimm et al 2000). However, healthy urban rivers can contribute to and support sustainable urban development through the supply of desired and valued ecosystem services (MEA 2005; Wangai et al. 2017). We argue that if African urban rivers are to be on an ecologically sustainable path, then a new approach that recognises the complexity of the interconnectedness and dynamic interactions between social and ecological systems within African urban landscapes, is required. Our research in the Nelson Mandela Bay Metro in South Africa and the Federal Capital Territory in Nigeria, which came to an end May 2021, focused on three key components of the notion of urban complexity in relation to urban river ecology and governance challenges: i) the imperative for developing multi-dimensional (ecological, social and economic) integrative indicators of urban river health; ii) institutional integration failure (i.e. silo operation) as a key governance challenge, and iii) the complex interactions and linkages between urban river health and people's social-economic well-being in river catchments.

Early results and engagement processes with stakeholders in the two catchments have highlighted additional challenges and concerns which deserved urgent scientific investigation, and in so doing extending and building on our current research projects. These additional challenges and concerns include

i) The proliferation of macro- (plastic size range 25 – 1000 mm), meso- (size range 5 – 25 mm) and microplastics (size range ≤ 5mm) in urban rivers, which have to date received little or no attention in these catchments and more widely in African water resources. Here, important knowledge gaps exist which include the influence of bio-habitat complexity on the dynamics of plastic pollutants, the influence of plastics on the assemblage distribution of biota in river systems, and plastic as potential vectors of pathogenic microorganisms and emerging pathogens.
ii) The governance of the water-land-agricultural nexus as a critical challenge to realising urban river health. For example, in both urban centres, land-based activities such as solid waste disposal have been implicated in contributing negatively to urban river health, implying the need for a nexus governance approach.
iii) The urgent need to examine urban river governance challenges, such as the regulatory system, cooperative governance, etc., in addition to institutional integration failure (which is already a subject of another project).
iv) The imperative to investigate the ethical implications of governance challenges in the context of social-ecological systems in urban landscapes.
v) And fundamentally, the criticality for long-term research project interventions in order to be able to monitor, track, and evaluate changes over time. The concept of river-people relationality, which we coined in our project, which come to an end in May 2021, has allowed us to begin investigation into people's values, perceptions, attitudes and behaviour in relation to urban rivers. However, the duration of research projects is usually short, often one to two years, as in our case, which makes tracking, monitoring and evaluating changes over time almost impossible. Stakeholders within the two catchments have expressed the desire for long-term intervention. Thus, there is a need to extend on-going research intervention in these area in order to track, monitor and evaluate shifts in perceptions, values, attitudes and behaviour in the selected catchments.

All the above-mentioned challenges deserve urgent investigation, particularly through long-term projects/programmes. However, for the purpose of the proposed project, the focus of the research will be on i) addressing urban river governance challenges, for example, the regulatory system, and cooperative governance and the ethical implications in the context of social-ecological systems, and ii) investigating the influence of bio-habitat complexity on the dynamics of macro-plastics and the assemblage distribution of biota in river systems, as well as examining whether macro-plastics support the establishment of pathogenic microorganisms and emerging pathogens, relative to the surrounding aquatic habitats.

We proposed to use the newly developed systemic-relational (SR) ethical approach by Odume and de Wet (2019) as the analytical lens for interrogating governance challenges and exploring their ethical dimensions. For example, a near absence of cooperative governance and failure of the regulatory systems has contributed to

i) illegal discharges of waste into urban rivers
ii) illegal abstraction of water from urban river resources
iii) the way in which people on catchment relate to and value urban rivers

These are matters of ethics as they relate to the law. For instance, the illegal discharges in the Swartkops River have negatively impacted on other water users who have a legitimate right to access these water resources, raising potential ethical concerns.

We take ethics as a systematic concern with the principles by which conduct, morals and values are clarified and justified, as we seek to distinguish between right and wrong in our behaviour towards other people and towards nature (Odume & De Wet, 2016). Overall, by situating the study within social-ecological system framing, which recognises that both social and ecological components form a unifying social-ecological system (SES), we are able to concurrently explore both ecological and governance dimensions of urban river systems.

Using two African metros, the Nelson Mandela Bay Metro in South Africa, and the Federal Capital Territory, Abuja in Nigeria as case studies, this research

i) examines the concept of African urban complexity by investigating urban river governance challenges, for example, the regulatory system, cooperative governance and exploring their ethical implication in social-ecological systems, and

ii) investigates the influence of bio-habitat complexity on the dynamics of macro-plastics and the assemblage distribution of biota in the selected rivers and

iii) examines whether macro-plastics support the establishment of pathogenic microorganisms and emerging pathogens, relative to the surrounding aquatic habitats.

The two case studies have been selected because for three reasons: first, they share similar features in that they are situated in large cities; secondly, our on-going project suggests similar governance and ecological challenges as already argued, and finally, FCT in Nigeria is strategic as the administrative seat of the Federal Government and any successful intervention in the FCT would likely influence the governance and management of urban rivers in the rest of the country.

SDG-pathfinding: co-creating pathways to sustainable development in Africa (SDG-pathfinding)

ON Odume, JL Tanner, CG Palmer, A Magwala and C Murata

June 2021 – December 2024

Sponsor: Belmont Forum via the National Research Foundation (NRF)
Collaborators: Dr Barbara Willarts IIASA, Austria; Olivier Barreteau INRAE France; Henri Mathieu Lo GAIA Senegal

The SDG-Pathfinding project contributes to the co-creation of sustainability pathways to meet multiple sustainable development goals (SDGs) in parts of Africa, through a bottom-up participatory approach that promotes cooperation and mutual learning across sectors and actors. Fimela district (Senegal), and the Swartkops catchment (South Africa), were selected as representative archetypal expressions of SDG-hotspots, that is, regions where multiple SDG gaps intersect.

The project adopts a systems approach to governance-biophysical global interactions. On the science frontier, the project co-develops a climate-friendly participatory scenario tool where stakeholders engage in a hands-on exercise to explore interlinkages and opportunities between resources, policies, institutions, and multi-actors involved in pursuing the SDG agenda. Using national and global narratives of future changes in climate, demographics, health, and economic development trends and uncertainties, stakeholders explore suitable policy interventions and innovative governance forms within their operating space to meet the SDG agenda, and identify the costs and benefits of action with respect to going BAU.

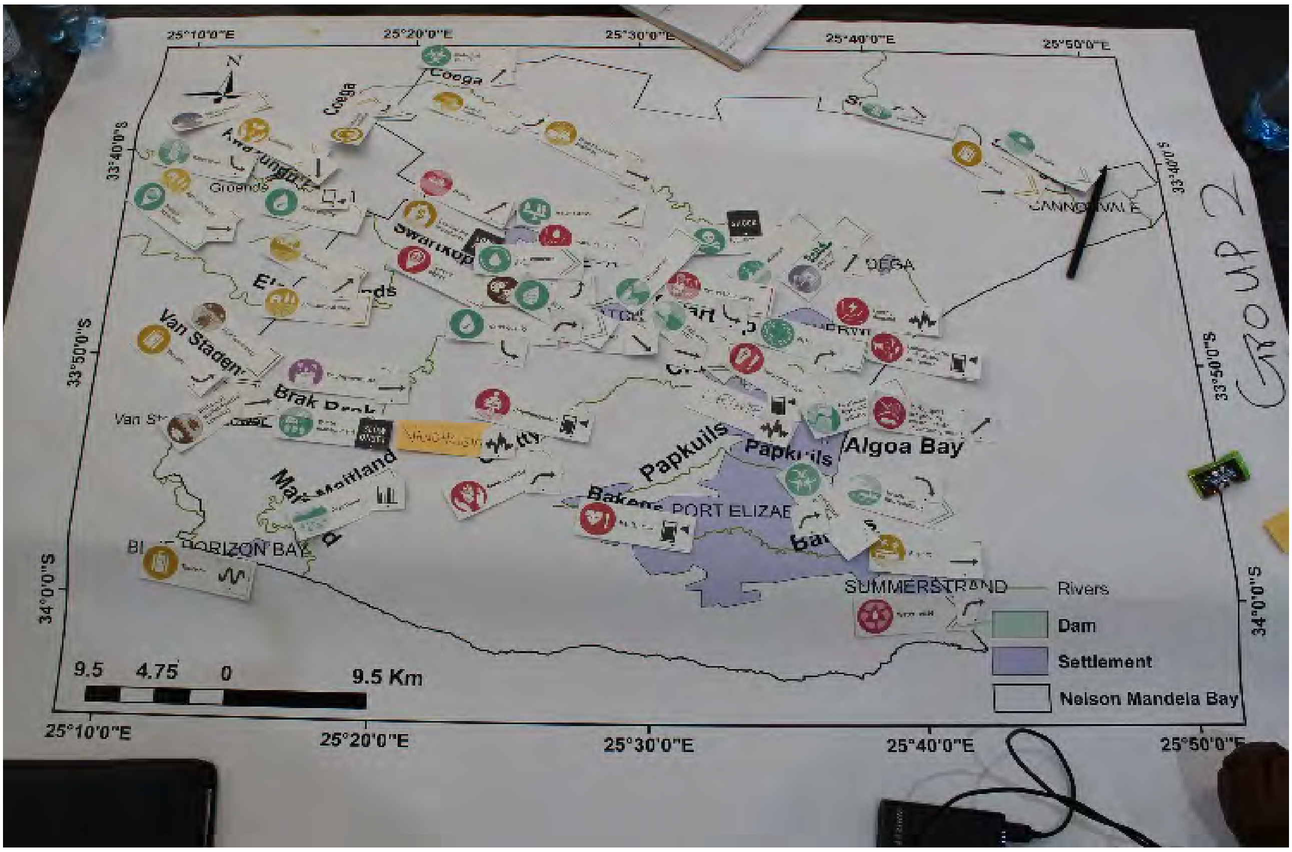
The SDG Living Labs are established in each of the two case studies, building on existing networks in a two-stage process: in Stage 1, stakeholders engage in developing a baseline assessment, that is, an understanding of what the specific governance barriers and opportunities to sustainability in each SDG-hotspot are. In Stage 2, stakeholders co-develop user-inspired, use-oriented sustainability vision(s), and the associated transformation pathways required to localise and support the implementation of SDG agenda at sub-national levels.

This mixed approach followed to date in this project helps to identify bottom-up means to overcome impediments to sustainability and resource equity taking into account national drivers and global changing conditions. The SDG-Pathfinding framework is flexible, transferrable, and broadly applicable to explore tailored SDG challenges and sustainability pathways.

Workshop participants during the catchment visioning exercise

Priority sustainability challenges identified by the workshop participants in the Swartkops case study in South Africa

Dimensions of the STEEP-H	**Identified priority sustainability challenges**
Social	Poverty
	Unemployment
	High levels of inequality
	High crime rate; safety and security concerns
	infrastructure vandalism
	High rate of unwanted pregnancies, abortion, and disposal of foetus into Swartkops River/Estuary
	Growing human population
	Under-serviced communities in terms of water and sanitation related services; poor sanitation-induced diseases
	Community release of solid wastes into river, impacting on spiritual use of water by the *Sangomas*
Technological	Maintenance of road networks
	Upgrade and maintenance of wastewater treatment works/technologies
	Upgrade and maintenance of urban storm water infrastructure
	Electronic waste management and the challenge of the electronic circular economy
	Old technologies being deployed in the agricultural sector and land management
Economic	Declining tourism potential of the Swartkops catchment due to pollution and reduction of the migratory bird population
	Declining property values in proximity of the Swartkops Estuary
	Industries support job creation, but are also major contributors to catchment pollution
Ecological/Environmental	Climate change, drought, and flash floods in low-lying communities and in informal settlements
	Fear of the so called "Day Zero" in the catchment
	Water and air pollution emanating from various sources, e.g., industries, informal settlements, road and rail networks
	Poor solid waste management e.g., plastics and electronic waste
	Discharges of occasionally poorly treated wastewater effluent from municipal wastewater treatment works into the Swartkops system
	Poor water quality from the Kat and Motherwell canals
	Invasive alien plants species in the catchment
	Biodiversity loss
Political	Governance failure - poor community participation, involvement and consultation in governance decision making
	Corruption and politics of exclusion
	Challenges with planning and implementation, particularly of the IDP
	Features heavily hierarchical and market-based governance, network governance not well entrenched
Historical	Legacies of historical apartheid spatial planning



Systems mapping of the Swartkops sustainability challenges

Innovative water infrastructure management to increase water security for people, economy and agriculture in Southern Africa (ECWASA)

ON Odume, CF Nnadozie, FC Akamagwuna and C Murata

April 2022 – March 2023

Sponsor: German Federal Ministry of Research and Education via Research Institute for Water Management and Climate Future at RWTH Aachen University

South Africa is prone to water scarcity and frequent droughts. The amount, duration and intensity of droughts has increased over the past decade. Although, in general, the condition of water and wastewater infrastructure is better than in other Southern African countries, the challenges are massive due to increased water scarcity, rapid population growth, energy shortages, and a decline of the water infrastructure resulting from low investments. The challenges are, amongst others, safe and sufficient drinking water supply, and a reliable sanitation system, especially for marginalised areas.

During droughts, the water supply is interrupted for industries and economies. The water demand for irrigation leads to groundwater over-exploitation and subsequent saltwater intrusion at coastal areas, which affects agricultural productivity. Furthermore, the low performance of municipal and industrial wastewater treatment plants deteriorates the quality of surface water via pollution by pathogens, nutrients, and persistent organic pollutants. These surface waters are the main drinking water resource for municipalities and industries. Owing to global warming and eutrophication, frequent cyanobacterial blooms are observed, accompanied by increased values of toxins. This topic is also relevant for German water utilities which use raw water from lakes and reservoirs. The planned project ECWASA will tackle these challenges by developing solutions for an improved water and sanitation infrastructure and infrastructure management in the water-food-energy nexus within the Buffalo City Municipality and the Kouga Local Municipality in the Eastern Cape.

A major outcome of this project was the ECWASA Springboard conference held on 23 February 2023 that showcased the key findings of the project, while identifying key water security challenges for the main project phase. The conference featured a broad range of presentations and discussions, providing an opportunity for delegates to share strategies, challenges, research and development needs, and investment opportunities. The Conference was opened by the Executive Mayor of Buffalo City Metropolitan Municipality, Cllr Xola Pakati, followed by the Executive Mayor of the Kouga Local Municipality, Horatio Hendricks, who presented their respective strategies and challenges in dealing with the water security challenges.

Mercedes-Benz South Africa (MBSA), a significant contributor to the region's economy, reported impressive results of their internal measures to reduce water consumption by 33%. Dr Chris Ettmayr from the Industrial Development Zone also discussed ongoing projects aimed at addressing the energy and water crisis. He identified the IDZ as a potential area where partners in the ECWASA project could explore and test innovative solutions.

During the conference, Prof. Oghenekaro Nelson Odume from the Institute for Water Research (IWR) at Rhodes University and Dr Manuel Krauss from the Research Institute for Water Management and Climate Future at RWTH Aachen University presented the research and development needs of the first phase of the ECWASA project. They outlined a strategy that involves water re-use, artificial groundwater recharge and strengthening the governance landscape towards achieving water security. This strategy includes pilot and demonstration projects embedded in ongoing South African-German initiatives. The presentation of this strategy demonstrated the coalition's commitment to addressing water security challenges and finding innovative solutions.

Dr Stanley Liphadzi, the Group Executive of the Water Research Commission, was also in attendance and presented the keynote address highlighting South Africa's economic water crisis that requires innovative measures, technologies, and management strategies to address.

A cross-section of delegates at the ECWASA conference

Cyanobacteria – the missing link in vibriosis dissemination

Sponsor: Swedish Research Council
Collaborators: Stockholm University, Sweden; Beirut Arab University, Egypt; Council for Scientific and Industrial Research, South Africa; Malawi University of Science and Technology, Malawi; Makerere University, Uganda.

Climate change is implicated in the spread of vibriosis, a group of diseases caused by *Vibrio* bacteria. Rising temperatures have increased the climate suitability for *Vibrio* worldwide, with ecosystem-wide impacts on humans and animals. However, in addition to the direct stimulation of *Vibrio* growth, the changing climate affects other ecosystem components, such as bloom-forming cyanobacteria that provide habitat and mediate *Vibrio* persistence in the so-called ecological reservoirs. In such systems, the infiltration of *Vibrio* to groundwater is more likely, and additional pressures, such as plastic pollution, accelerate the spread of these bacteria.

The project proposed to develop a framework for the assessment of *Vibrio* ecological reservoirs and to apply this framework for predicting the diversity and load of *Vibrio* in ecosystems with regular cyanobacteria blooms. A team of ecologists, microbiologists, chemists, and hydrologists will explore the role of cyanobacteria-driven *Vibrio* propagation across the freshwater and brackish systems in the Baltic region and Africa. We will also link *Vibrio* communities in the surface waters to those in groundwater, and evaluate how plastic litter and water use behaviour of humans may affect *Vibrio* persistence in countries with water scarcity. Our findings will contribute to capacity building for microbiological monitoring in developing countries and the development of ecosystem-based management of water resources in Africa.

Investigation of the occurrence and risk of infection of pathogenic and antibiotic resistant *Campylobacter* species in selected source waters within the Kowie catchment, Eastern Cape, South Africa

CF Nnadozie and ON Odume
1 April 2019 – 31 March 2023

Sponsor: Water Research Commission

In the last decade, the discovery of *Campylobacter* spp., an emerging pathogen, has now become a serious public health concern. These infections are a main cause of gastrointestinal disease globally, and their occurrence rates are higher than those caused by *Salmonella* and *Shigella* in developed countries.

Locally, diarrhoea is the third leading cause of death, and approximately R3.5 billion is spent annually on gastrointestinal diseases. To complicate issues, the high prevalence of resistance in clinical isolates of *C. jejuni* and *C. coli* to first-line antibiotics (fluoroquinolones, macrolides and tetracycline) that are used for treatment have been reported in both developed and developing countries. The impact cannot be overlooked, particularly in South Africa with its high population of vulnerable individuals, for several reasons, including HIV/AIDS.

Campylobacter infections are caused through ingesting contaminated food, but the primary reservoir of these pathogens are animals, faecal-contaminated water, or the environment. The Kowie River in Makhanda, the Eastern Cape, is used by the community for recreational, irrigation and spiritual (e.g., baptism) purposes. This river system is subject to various kinds of microbial contamination that poses a health risk to humans. Makhanda and the surrounding areas face a sewage treatment crisis, and raw sewage commonly flows into streams and rivers that eventually reach the Kowie River. Livestock farming is a common practice in the area, and much of the runoff containing manure from livestock from nearby farms and grazing commonage flows into the river, severely polluting it and affecting water quality.

Studies have reported the presence of sub-therapeutic levels (in the range of ng/l) of antibiotics in surface waters locally, which can act as selective pressure for pathogens to develop antibiotic resistance in pathogens within the environment. While there are no documented waterborne outbreaks of *Campylobacter* gastroenteritis in South Africa, small-scale local studies demonstrate that the rates of *Campylobacter* infections might be underestimated. Among those, 801/848 of isolates that were submitted by the Group for Enteric, Respiratory and Meningeal Surveillance in South Africa (GERMS-SA) laboratories from different provinces in South Africa for a *Campylobacter* Surveillance Programme, were positive for species of *Campylobacter*. This information and these statistics are from clinical surveillance programmes, but without a linkage with the environment. Yet we know that the environment is a reservoir of resistant bacterial strains and antibiotic-resistant genes that, with time, can potentially be incorporated into human as well as passing pathogens through horizontal gene transfer. It is against this background that this project is initiated, to investigate the incidence and risk of antimicrobial-resistant *Campylobacter* infections from a One Health perspective. The One Health perspective recognises that human health, animal health, and the environment are interconnected. *Campylobacter* is a typical example of a One Health challenge which has emerged at the human-animal-environment interface. Given the role of surface water in spreading antimicrobial resistance in humans, the goal is to develop a framework for human health risk assessment on account of exposure to antibiotic-resistant *Campylobacter* from river water.

Investigating the multiple risk dimensions associated with *Campylobacteriosis* – a key poverty-related disease of South African urban source water environments

CF Nnadozie

July 2021 – July 2024

Sponsor: European Union and Foundation Botnar

South Africa remains one of the countries in the world with the widest disparities in wealth and access to resources. The majority of the population is overburdened with poverty-related diseases (PRD) such as HIV-AIDs, tuberculosis, and diarrhoea. Despite the incidences of diarrhoea being as high as 10 per 1000 of children admitted to a tertiary hospital in South Africa, the disease has not received much research attention compared to other PRD such as HIV/AIDS and tuberculosis. *Campylobacteriosis*, a disease caused by *Campylobacter* spp., is the main cause of diarrhoea globally and in South Africa. Another critical dimension of *Campylobacter* infection of urgent relevance in South Africa is Guillain-Barré syndrome (GBS), a neurological condition in which the body's immune system incorrectly attacks part of its peripheral nervous system. Ingestion of faecal-contaminated water is a principal risk factor for *Campylobacteriosis*. In South African urban centres, wastewater treatment works are overloaded, resulting in the discharge of poorly treated effluents into the receiving rivers. The urban poor, children and mothers, as well as the adolescents who largely depend on rivers for recreational activities, spiritual activities such as baptism, harvesting of medicinal plants from the riverside, and fishing, are the most at risk of *Campylobacteriosis*. Given the link between diarrhoea, poverty, and environmental quality/sanitation, a more integrated, systemic approach that pays attention to the multiple risk dimensions associated with *Campylobacteriosis* is crucial. Mapping the incidences of urban poverty, service delivery failure, as well as *Campylobacteriosis*, can provide policymakers with much-needed insights for comprehensive strategies to reduce the occurrence and potential risk associated with the disease in South Africa.

Microbial risk assessment is useful for estimating microbial risks associated with contaminated surface water. The difficulty of culturing *Campylobacter* spp. for risk assessment studies can be circumvented by using next generation sequencing (NGS). By applying shotgun metagenomics, it is possible to sequence all the micro-organisms within an environment to identify infectious etiologies and then, by applying machine learning algorithms (MLA), to predict the risk from shotgun metagenomic sequences of an environmental sample. This project will combine multiple approaches: NGS, MLA, microbial ecology, and risk mapping to attempt an integrated study of *Campylobacteriosis,* a key PRD in South African urban environments. The Swartkops River in the Nelson Mandela Bay Municipality (NMBM) and the Kowie River of Makana Local Municipality, Eastern Cape, South Africa, are to be investigated in this study.

African urban complexities and the governance challenges of urban rivers – a systemic-relational inquiry

FC Akamagwuna, C. Murata, CF Nnadozie and ON Odume

Sponsor: African Multiple Cluster of Excellence
Collaborators: GO Omovoh, Federal Ministry of Environment, Nigeria; BN Onyima, Anthropology, Nnamdi Azikiwe University; Okeja Uchenna, Philosophy Department, Rhodes University

The trajectory of urbanisation in Africa is complex, presenting potentially intractable governance challenges to natural resources, such as urban rivers. Part of this intractability arises because of insufficient appreciation by urban planners and policymakers in Africa of the interconnectedness and interdependence between ecological and social sub-systems within an urban landscape (Grimm et al., 2000). In Africa, urban river systems are often seriously degraded, and recent empirical evidence suggests the accumulation of novel pollutants such as macro- and microplastics in such river systems (Grimm et al., 2000). However, healthy urban rivers can support sustainable urban development by supplying desired and valued ecosystem services (Wangai et al., 2017). In this project, we argue that if the trajectory of African urban rivers is to be on an ecologically sustainable path, then a paradigm shift towards an approach that recognises the complexity of the interconnectedness and dynamic interactions between social and ecological systems within African urban landscapes is required.

In this project, we build on our existing projects on water ethics and governance challenges and ways of enhancing African urban ecosystem health which suggest that urban rivers pose unique governance challenges because of their location within urban catchments and consequent severe ecological degradation. We propose to use the systemic-relational (SR) ethically grounded approach (Odume & de Wet, 2019) as an analytical perspective for investigating the governance and ecological dimensions of urban river systems. The approach recognises that ecological and social-economic components of urban landscapes form an integrated and dynamic complex system of urban river catchments. These two major components are in ongoing complementary and co-supportive interactions with multiple, cross-scale dynamic feedbacks. Further, the SR approach recognises the centrality of values and the potential role of ethics in negotiating and constructively balancing conflicting values to realise healthy urban river ecosystems in African urban landscapes (Figure 1).

The proposed project covers two substantial grounds: i) to contribute empirical evidence to policy on urban river governance challenges and their ethical implications, considering the multi-faceted issues associated with African urban complexities, and ii) to contribute important ecological data on the dynamics of emerging pathogens, biota and macroplastics. Altogether, our intention is to stay put, particularly in urban river catchments, long enough to shift policy and practices regarding i) the governance of urban river systems, ii) institutional and societal values informing behaviour towards urban rivers, and iii) the management of novel pollutants. Overall, these contributions will be achieved through the following research objectives:

i) Examining the concept of African urban complexity through an investigation of urban river governance challenges, for example, the regulatory system and cooperative governance and their ethical implications in the selected metros (Nelson Mandela Bay in South Africa and the Federal Capital Territory in Nigeria);
ii) ii) Investigating the influence of bio-habitat complexity on the dynamics of microplastics and the distribution of biota in the selected rivers;
iii) Examining whether macroplastics support the establishment of emerging pathogens relative to the surrounding aquatic habitats.

Figure 1: IWR post-doc, Dr FC Akamagwuna, paddling in a canoe in the Pere Marquette River in Grand Rapids, Michigan, as a Cohort of the Society for Freshwater Science Emerge Fellowship 2022.

IWR post-doc, Dr FC Akamagwuna, presenting at the Joint Aquatic Science Meeting in Grand Rapids, Michigan, the USA, May 15 2022.

Water quality modelling and scenario analysis of the Leeuspruit River in support of the G4 closure process of Sigma Colliery

AR Slaughter, NJ Griffin and ON Odume

August 2022–January 2023

Sponsor: Sasol Mining

Sigma Colliery is a defunct coal mine that was operated by Sasol Mining (Pty) Ltd. It is situated to the north, west and south of Sasolburg in the Free State. Sasol is taking steps to close the Sigma Colliery. As a part of this process, potential impacts and mine water management considerations for mine closure need attention. The best practice guidelines (BPG) for this aspect of mine closure are the best practice guidelines of the Department of Water and Sanitation that use source-pathway receptor and risk-based approaches to mine water management. Sasol will have to comply with the outline requirements of the BPG G4 impact prediction and BPG G5 water management aspects for mine closure.

The closure of Sigma Mine requires that water quality impacts on Vaal River Water are curtailed. Although the Leeuspruit carries a load of salinity (mostly as sulphates) and nutrients (most notably, as phosphate), previous surveys have found no impact of Vaal River water quality where the Leeuspruit joins the Vaal River. However, downstream assessments of Vaal River water quality (highway bridge over Vaal River) show decreased quality and there is concern that decant from Sigma Colliery may be responsible for this.

In order that impacts are limited, we will model surface water quality in the Leeuspruit and Vaal Rivers to simulate water quality in the region. This would require modelling water quality in the Rietspruit (north bank) as this affects the Vaal River water quality. Finally, the water model will be used to assess the impact of mitigation through scenario analysis which will use a water quality model for the Vaal Barrage developed in the prior research project.

Revision of the 1996 South African Water Quality Guidelines: development of risk-based approach using aquatic ecosystems responses

L Ncube, N Griffin, ON Odume, PK Mensah and E van Niekerk

April 2020–January 2023

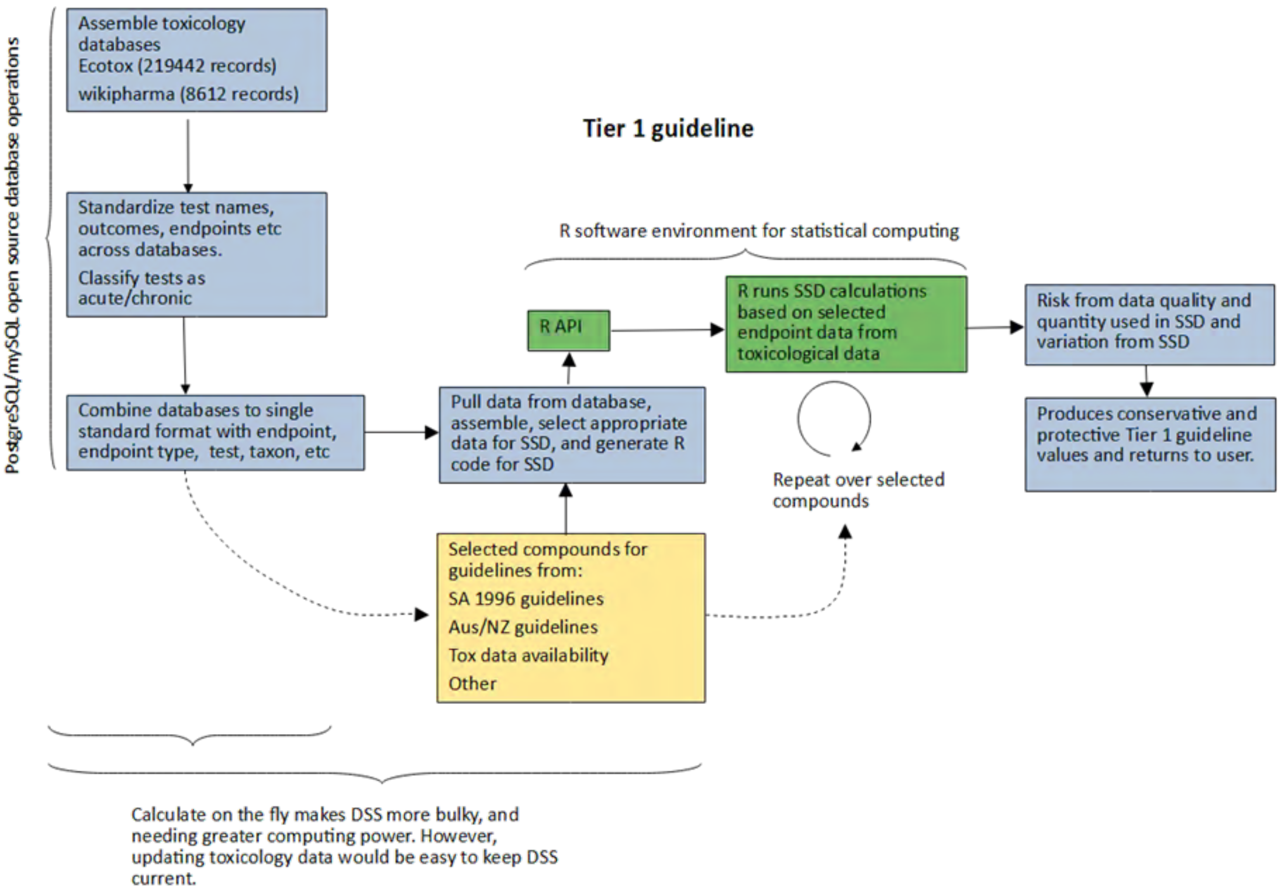
Sponsor: Water Research Commission

This research project focuses on the revision of the 1996 South African Water Quality Guidelines (SAWQG) for freshwater ecosystems, with a view to developing risk-based guidelines operationalised through a software-based decision support system. The final system will have spatially specific guidelines for a greater number of parameters than the 1996 guidelines. This approach follows the revision of water quality guidelines for other water users in South Africa.

The imperatives for the project arise out of the realisation that the 1996 water quality guidelines have limitations in several important areas, including i) non-alignment with approaches to water resource protection, ii) insufficiently risk-based, iii) lack of internal coherence between guidelines for different users, iv) not a reflection of the full range of critical water quality variables such as persistent organic pollutants (POPs), pesticides and endocrine disrupting compounds (EDC), despite local and international research regarding these variables. The project intends to address these shortcomings through the development of a multi-tier decision support system (DSS) allowing for risk identification, analysis, and management. The overarching aim of the current project is to review and develop an electronic-based decision support system (software) able to provide both site-specific and generic risk-based water quality guidelines for South African aquatic ecosystems.

Production of risk-based guidelines will be data based, and data on responses of taxa to stressors, as well as data on ambient spatially specific water quality will be required to generate suitable guidelines. The project has gathered 219 442 toxicological results from international databases, as well as 332 084 water quality records from regularly monitored sampling points around the country, and data collection is continuing.

The project team attended one planning workshop in Maputo where considerable progress was made in the design of three tiers. Tier 1 is conservative and guided by multi-taxon toxicological responses; Tier 2 is site-specific and modified to reflect local water quality, and Tier 3 is being refined. The abovementioned datasets are incorporated into a DSS where guidelines can be generated from these data.



Schematic for Tier 1 conservative guideline generation from toxicological data

Developing long- and short-term technical solutions, mitigation measures and decision support strategies that will improve water quality in the Grootdraai Dam catchment

AR Slaughter, NJ Griffin, ON Odume and FC Akamagwuna

March 2022–March 2024

Sponsor: Water Research Commission

The deteriorating water quality in the Grootdraai Dam catchment (GDC) above Standerton has serious economic, social, and ecological implications because of its strategic importance to the South African economy. On the economic front, pollution has affected the quality of the raw water, and thus the operations of industries relying on raw water. Some of these industries have had to abstract more water to fulfil their operational needs, but this is not sustainable in the medium and long term due to water scarcity within the catchment. The poor quality of the raw water also implies that it becomes more costly to treat abstracted water to standard fit for industrial use, which then contributes to the variable and operational costs of these industries and, in the long term, can lead to job losses and put into jeopardy the viability of the operations of raw water-dependent industries in the catchment. It is critical that the development of water quality predictive models and DSS for the GDC take into account i) current and future hydrology of the catchment; ii) current and potential future land-use cover and change within the catchment; iii) all major sources of water quality impacts (natural and human-induced, historical, current and planned); iv) current and predicted climate conditions; v) seasonal complexity; vi) water quality variables of management concerns; vii) the link between discharge standards and management goals; viii) catchment sensitivity to current and planned activities of water quality significance, and ix) stakeholder relationships within the catchment, for example, upstream-downstream relationships, lateral, vertical – in the case of users that impact atmospheric depositions, which then impact water quality of the catchment.

The project team are engaging stakeholders in the catchment and will continue in this regard. The Department of Water and Sanitation (DWS) datasets for the catchment have been obtained, and Rand Water data have been requested. These data will underpin modelling of water quality and scenarios in the catchment.

Microplastics as emerging contaminants: methods development, ecotoxicity testing and risk assessment towards freshwater resource protection in South Africa

N Mgaba, NJ Griffin, PK Mensah and ON Odume

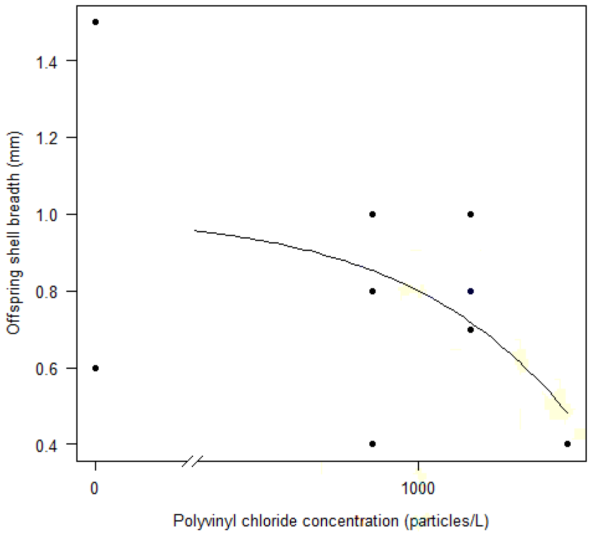
April 2019–March 2022

Sponsor: Water Research Commission

Microplastics have been described as emerging pollutants accumulating in aquatic environments worldwide. To gain a clearer understanding of the availability of microplastics and the threat they pose to aquatic life and ecological processes, it is important to obtain accurate measures of their abundance in surface water, sediments, and benthic organisms. Previous research shows that microplastics can be harmful to aquatic organisms such as fish and invertebrates because they can constitute a threat as chemical and physical stressors. As chemical stressors, the chemical makeup of microplastics can leach, potentially posing a threat to aquatic life and the environment. As physical stressors, microplastics can cause abrasion to soft tissues, accumulate in and block such tissues, potentially posing a significant risk. A third dimension, which will not be investigated in this project, is that microplastics can act as vectors transporting both chemical pollutants and pathogenic microorganisms. Thus, the aim of this WRC-funded project is to evaluate the potential toxicity of microplastics as chemical and physical stressors and to develop/adapt methods for such studies.

A number of toxicological tests were undertaken assessing the impacts of physical microplastic particles and three selected plasticisers on a range of endpoints in fish (*Danio rerio* and *Tilapia sparramanii*), snails (*Melanoides tuberculata*) and shrimps (*Caridina nilotica*). Endpoints assessed included stress enzymes, and various measures of growth and reproduction.

Testing and data analysis is complete and the final report has been submitted. In short, identified toxicological impacts of microplastic particles at environmentally realistic levels was limited; however, toxicological tests on plasticiser revealed certain of these to have negative effects on enzyme systems in particular. In addition, a survey of local rivers established that microplastics are widespread in the environment.



Dose response curve showing the impact of polyvinyl chloride particles on growth in young snails

Photo by Alexander Schimmeck on Unsplash

Macroplastics in the environment: are they suitable habitats for macroinvertebrates in selected headwater streams?

Student: AA Ali
Supervisors: ON Odume and CF Nnadozie
Degree: MSc (Water Resource Science)

Overview

Macroplastics are ubiquitous in the environment and have been recognised as one of the leading causes of aquatic ecosystem deterioration (Zalasicwicz *et al.*, 2016). The increased plastic accumulation in the environment has been linked to their high production, low recycling, and degradation rates (Sigler, 2014). Once released into the environment, plastic materials with a diameter ≥ 25 mm are commonly considered macroplastics and have been shown to have various direct and indirect effects on aquatic organisms (Lippiatt *et al.*, 2013). For example, macroplastics are a known secondary source of microplastics (Browne *et al.*, 2008), and their interaction includes plastic-species ingestion (Boginagwa *et al.*, 2016), plastic-species entanglement (Allen *et al.*, 2014), and they potentially absorb other pollutants (Rochman *et al.*, 2013). Many plastic dynamics, such as size, makeup, transport and lack of degradation may contribute to the displacement of natural microhabitats – potentially impacting habitat heterogeneity, quality, stability, and diversity of aquatic ecosystems. However, knowledge of macroplastic impacts on freshwater ecosystems is limited, despite being one of the most recent causes of water quality and habitat deterioration in rivers and stream ecosystems worldwide.

In freshwater ecosystems, natural micro-habitats are characteristically different and play critical roles in shaping the distribution of benthic communities (Dallas, 2007). Microhabitat determines the natural assemblages and distribution of aquatic animals, including macroinvertebrates, as they exhibit varying preferences for environmental conditions and habitat quality (Czerniawska-Kusza, 2004). The proliferation of microplastics in freshwater ecosystems can lead to the formation of artificial microhabitats in rivers and streams, thereby affecting the natural characteristics of stream habitats. Thus, there is a potential for macroinvertebrates to colonise the artificial microplastic habitats, which can have severe implications for the natural distribution of aquatic biota and ecosystem function, including food webs. However, the biological colonisation of artificial macroplastic habitats and its effects on macroinvertebrate distribution in freshwater ecosystems has not been adequately investigated. Furthermore, their interaction with the immediate environment is based on the combination of traits that they possess, enabling them to survive and adapt.

To better understand macroplastics' impact on habitat quality and macroinvertebrate assemblage, I asked if macroplastics are suitable habitats for macroinvertebrates in selected headwater streams in Eastern Cape Province, South Africa. Headwater streams are the first expression of flowing freshwater ecosystems (between a spring and a stream), and they provide essential water sources, sediments, and biota outside of other anthropogenic influences.

Objectives

1. To assess the influence of hydraulic biotopes on the taxonomic assemblage structure of macroinvertebrates on macroplastic substrates in selected headwater streams;
2. To assess the influence of exposure duration on the establishment of macroinvertebrate assemblage on macroplastic substrates in selected headwater streams;
3. To analyse the distribution of macroinvertebrate traits and ecological preferences on macroplastic substrates in selected headwater streams.

Progress

A manipulative field experiment was conducted for 180 days in four selected headwater streams of the Eastern Cape (Bloukrans, Buffalo, Kat and Swartkops Rivers). With an interval of 30 days between sampling events, macroinvertebrates and environmental variables were observed in a variety of hydraulic biotopes within each site (location factor) and various substrate levels comprising a natural substrate (NS), a mixture of a natural and plastic substrate (NP), and plastic-dominated substrate (PD) as treatment factor. Generated data are being analysed to answer the above objectives, and I am currently making sense of the data and writing up my thesis.

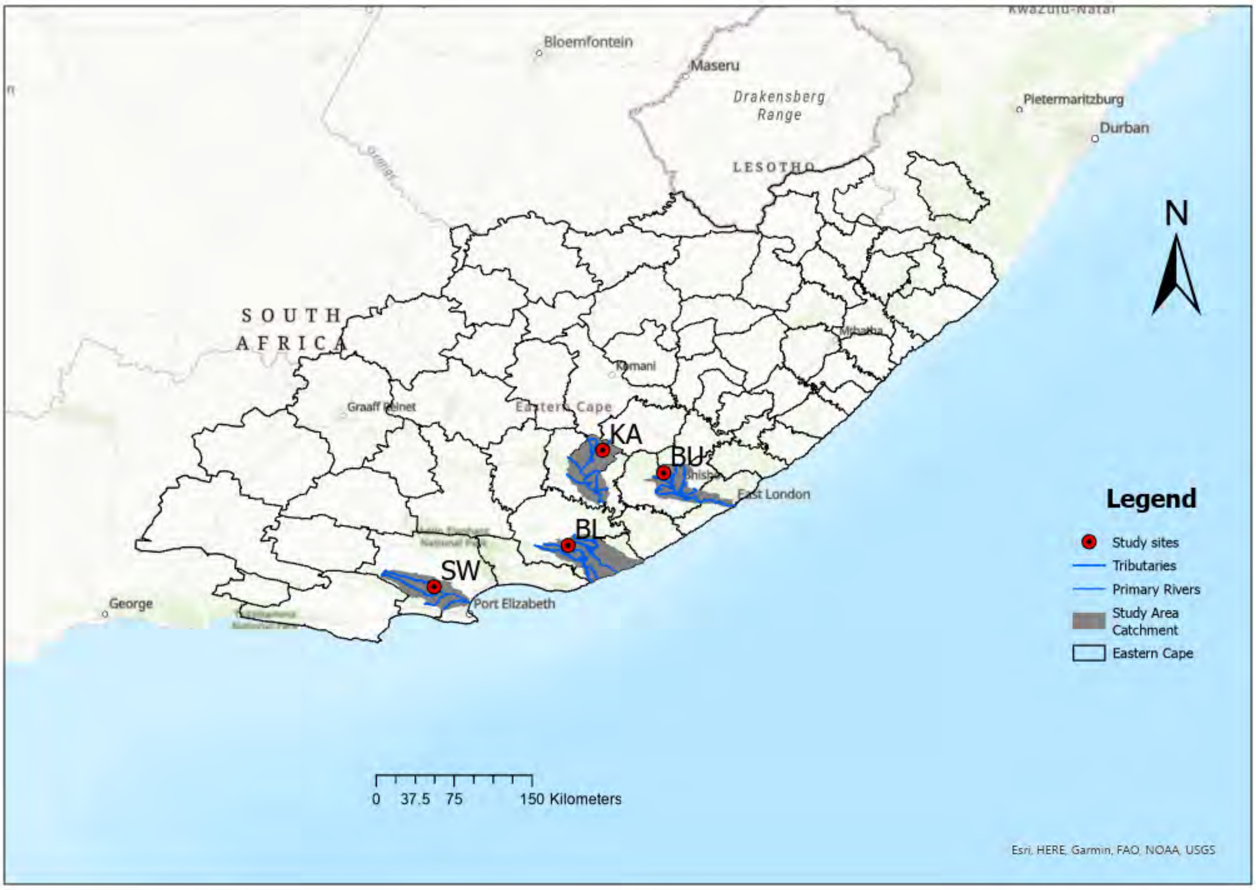


Figure 1: Photo showing the Eastern Cape boundary within South Africa with study sites from the four selected river catchments.

Figure 2: Andrew Ali retrieving deployed artificial substrate (left) and retrieved plastic substrates and macroinvertebrate samples (right).

Preliminary Findings

Forty-eight macroinvertebrate taxa identified at the family level were recorded. The contribution of a gradient of plastic substrates to the abundance of macroinvertebrates encountered is relatively in the order NP>PD>NS. Despite the observed differences in macroinvertebrate count on the gradient of substrates, only Simpson's diversity indicated a negligible difference in macroinvertebrate structural assemblage. The contribution of hydraulic biotopes based on the multivariate analysis conducted to envisage the performance of gradient of plastic was indifferent in all but Pool biotope, which indicated differences in terms of species richness on a natural substrate (NS) assemblage compared to other substrate groups.

It was established that different gradients of plastic substrates (NP and PD) support the colonisation of macroinvertebrates. The dominance of macroinvertebrates on the plastic gradients compared to the NS was likely owing to species such as the family Chironomidae, abundant throughout the study period. This family is known as a generalist species as they usually do not have a preference for specific habitats. However, the high richness observed on NS substrate both on the combined data and Pool biotope as compared to NP and PD could indicate that plastic substrate in a particular flow habitat type may reduce the diversity of macroinvertebrates and increase the occurrence of opportunistic species in such habitats. Regardless of the type of influence brought about by any gradient of plastic habitat, plastics can only be a temporary habitat and of no nutritional value to biodiversity.

Source attribution and human health risk assessment of antibiotic resistant *Campylobacter* in Bloukrans and Swartkops Rivers in the Eastern Cape, South Africa

Student: M Chibwe
Supervisor: CF Nnadozie and ON Odume
Degree: PhD (Water Resource Science)

Rivers serve as source water for drinking, irrigation, a place for recreation, spiritual and cultural activities. Yet they are increasingly polluted with human and animal pathogens of enteric origin. These pathogens originate mainly from urban run-off, faecal contaminated soil, animals, poorly treated wastewater from nearby wastewater treatment plants, and effluent from livestock farms. Polluted rivers act as transmission routes and reservoirs for many pathogenic micro-organisms, including the antibiotic resistant ones. The occurrence of Antibiotic Resistant Bacteria (ARBs) and Antibiotic Resistant Genes (ARGs) in the water bodies is a global concern as the ARBs can be transmitted to humans on exposure to contaminated water. These ARGs can be acquired from the environment by clinically relevant pathogens in the rivers.

Campylobacter species are among the leading etiological agents for gastroenteritis in humans worldwide. Antibiotic resistance of bacterial pathogens, such as *Campylobacter* and other pathogens, leads to increased hospitalization and mortality rates of infected patients as infection caused by ARBs is becoming difficult to treat. In different parts of the world, isolates of *Campylobacter jejuni* and *Campylobacter coli* have shown resistance to erythromycin, azithromycin and clarithromycin), amoxicillin, fluoroquinolones (ciprofloxacin) and tetracycline, which are the recommended antibiotics for treating campylobacteriosis.

Transmission of pathogenic *Campylobacter* species is through faecal contaminated water and zoonotic sources. Consumption of faecal-contaminated water is a major risk factor for transmission of *Campylobacter* species. Poorly treated wastewater discharge, urban run-off, agriculture effluent, faecal matter from animals from nearby farms is often discharged into the Bloukrans and Swartkops rivers. Therefore, these rivers may play a critical role as transmission routes and reservoirs for many pathogenic micro-organisms, including the antibiotic resistant ones. This project assesses the human health risks posed by the presence of antibiotic resistant (AR) *Campylobacter* species in the Bloukrans and Swartkops rivers, Eastern Cape, South Africa. It aims to identify the leading source of ARB pollution in these rivers. Local cases of human antibiotic resistant *Campylobacter* species/genes will be linked to the identified sources, and an indicator pathway for infection will be developed. The outcome of this study will inform management and intervention strategies, and how to effectively safeguard people from exposure and promote public health.

The research outputs for this project so far include a systematic review paper on the prevalence of antibiotic resistant *Campylobacter* in South Africa (currently under review) and a number of other manuscripts which are currently being worked on. Results on the spatial and temporal occurrence of *Campylobacter* in the Bloukrans and Swartkops rivers were presented at the Rhodes University Centre for Postgraduate Studies conference in September 2022.

Figure 1: Cattle grazing on the Bloukrans River

Water quality assesment in the Grootdraai Dam Catchment using WQSAM under various scenarios

Student: S Lazar
Supervisors: N Griffin and FC Akamagwuna
Degree: MSc (Water Resource Science)

The Vaal River system is the most highly developed and regulated river in South Africa and is considered the main water source for central industrial mining and metropolitan regions in the country (Pitman et al., 2002). The Grootdraai Dam catchment in the Upper Vaal supports agriculture, residential, mining, and power generation. The primary sources of water quality degradation in the Grootdraai Dam catchment can be defined as a non-point source, such as runoff from an agricultural area, or as a point source, such as effluent released from the coal mining with high total dissolved solids (TDS) (Strauss, 2006).

South Africa is a country that experiences many of the consequences of climate change in terms of water quantity and water quality which influence the life of aquatic ecosystems, environmental biodiversity, and people's lives. Management strategies and safety measures have been implemented, but water quality continues to deteriorate. Challenges to both surface water and groundwater quality are salinity, pH, metals, nutrients, and other elements (DWA, 2011). Mining operations have a profound influence on hydrology and water quality in the Vaal River system, and can even affect the quality of the groundwater. Acid mine drainage causes high salinity and sulphate contamination of the water, and is a potential source of heavy metal pollution.

This research uses the Water Quality Systems Assessment Model (WQSAM) for water quality modelling, which links flow and water quality (Slaughter et al., 2017). The WQSAM will be applied to assess various possible scenarios that can be divided into short-term and long-term scenarios in the catchment. The outcome of the research is to identify how to sustainably manage the resource in the Grootdraai Dam catchment in the future.

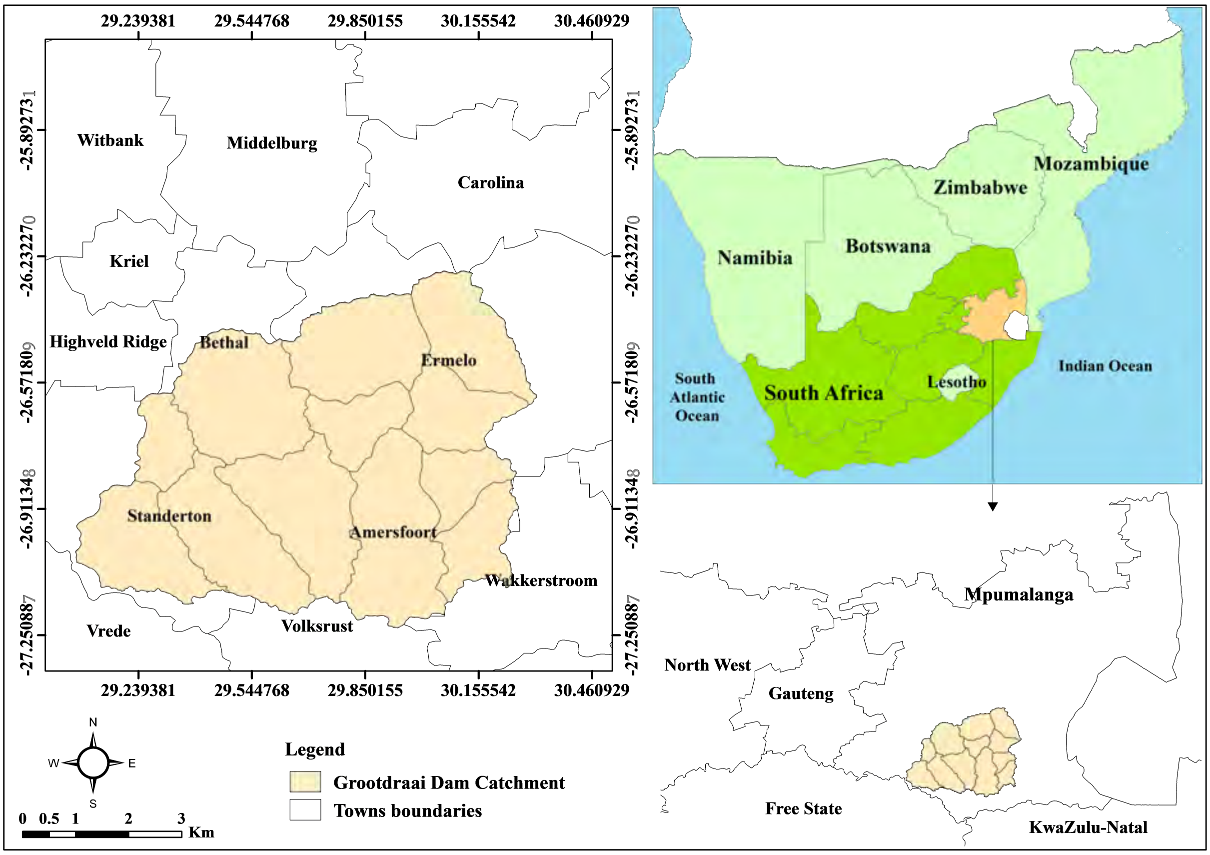


Figure 1: Location and digital elevation of the Grootdraai Dam catchment.

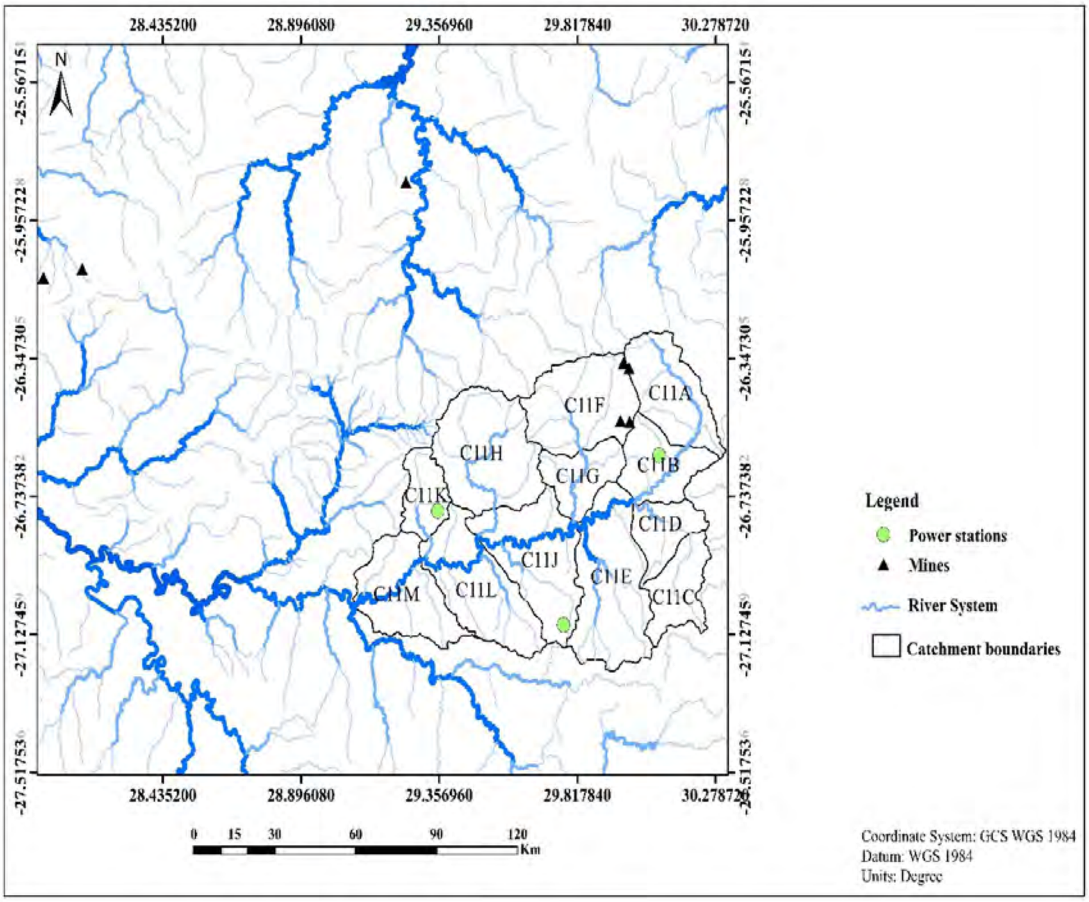


Figure 2: Illustration of the coal mining and industries within the hydrographic system of the Grootdraai Dam Catchment.

Developing ecotoxicological methods for evaluating the potential effects of microplastics at environmentally realistic concentrations in South African freshwater systems

Student: Z Mtintsilana
Supervisor: N Griffin
Degree: MSc (Water Resource Science)

Plastic production has increased drastically worldwide over the last 50 years, increasing from 0.5 million tonnes per year in 1960 to roughly 300 million tons in 2013 (Neufeld et al., 2016). Larger plastic particles can break down over time as a result of different processes, to form smaller plastic particles ≤ 5 mm in diameter called microplastics (Ling et al., 2017). Microplastic pollution can be distributed in a wide variety of habitats, such as terrestrial, aquatic, and alpine environments, in the air, and in both the Arctic and Antarctic (Morgana et al., 2018; Gasperi et al., 2018). According to the literature, microplastics exposure is a stressor and can be associated with several negative effects on organisms from multiple trophic groups, such as reduced food consumption, excessive weight loss, reduced growth rate, blockage of gills, decreased energy, and negative impacts on successive generations (Au et al., 2015; Lusher et al., 2017; Ortiz-Villanueva et al., 2017). It is important to investigate the effects of microplastics in freshwater systems as there is a lack of studies, especially in South Africa (Nel & Froneman, 2015; Au et al., 2015; Pereao et al., 2020). This research aims to contribute to the development of methods for assessing the potential ecotoxicity occasioned by microplastics in South African freshwater systems.

The microplastic polymers chosen for the study were polyvinyl chloride (PVC), polyethylene (PE) and polypropylene (PP). Using a series of lab exposures, different endpoints such as growth and reproduction were tested on the organisms *Melanoides tuberculata* (snails), *Caridina nilotica* (shrimps) and *Tilapia sparrmanii* (fish). Each experiment had three replicas and ran for 21 days.

Figures 1, 2 and 3 illustrate dose-response curves showing offspring production per adult snail in varying concentrations of PP, PVC, and PE suspensions. For all polymers tested, the curve-fitting algorithms showed that there was no clear response of snails to the microplastics across the concentration ranges tested, meaning none of the microplastic types, nor the concentration ranges affected the reproduction of the snails. This is common in chronic ecotoxicological studies. For example, Weber et al. (2021), also discovered that microplastic exposure had no significant effect on the reproduction of *Lymnaea stagnalis*. The results of Weber et al. (2021) indicate that the detectable impacts of microplastics were generally too small to detect statistically, which is similar to the results of the current study. This research project is in the stage of data analysis.

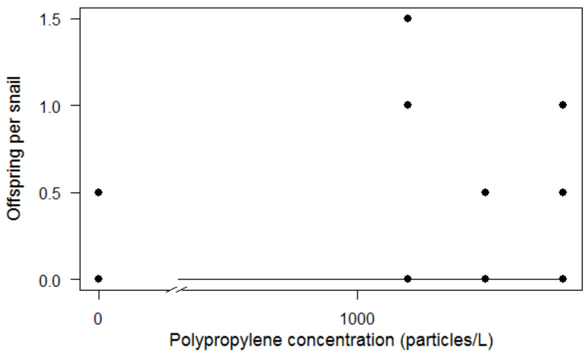


Figure 1: Dose-response curve showing offspring production per adult snail in varying concentrations of PP exposures.

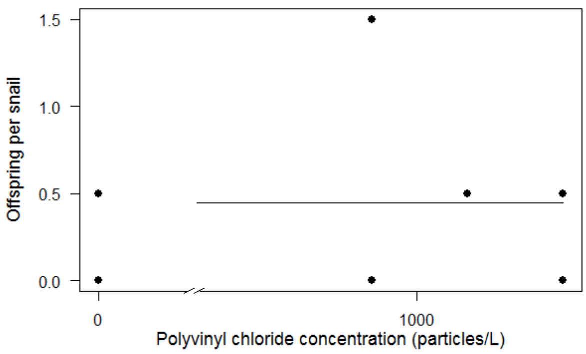


Figure 2: Dose-response curve showing offspring production per adult snail in varying concentrations of PVC exposures.

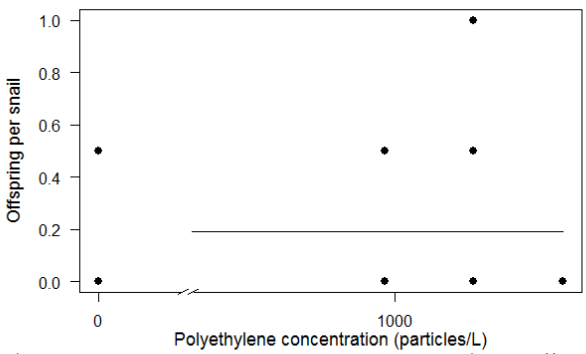


Figure 3: Dose-response curve showing offspring production per adult snail in varying concentrations of PE exposures.

Investigation of methods of detection of *Campylobacter* spp. from river water samples in the Bloukrans River, Eastern Cape

Student: N Ngoni
Supervisors: Dr C Nnadozie and Prof. C Knox
Degree: MSc (Water Resource Science).

Abstract

The *Campylobacter* bacteria are the leading cause of diarrheal disease globally, and in South Africa, diarrheal disease is the third leading cause of death. Consumption of and contact with water contaminated by faeces is a major risk factor for transmission of these organisms to humans. Because South Africa is a water-scarce country, many South Africans rely on their freshwater systems, including rivers, for recreation and domestic and agricultural activities. However, most rivers in South Africa are heavily polluted with faecal pathogens discharged from insufficiently treated wastewater treatment plant effluent, from runoffs from manure-treated crop farms, and excreta from nearby grazing livestock. Therefore, the rivers represent all risk factors for *Campylobacter* pollution and human exposure.

Campylobacter detection in a water sample is critical to ascertain potential risks to humans. However, methods to recover *Campylobacter* from river water samples are lacking. This study is part of a larger WRC-funded project investigating the occurrence and risk of infection of pathogenic and antibiotic-resistant *Campylobacter* species in selected source waters within the Kowie Catchment, Eastern Cape, South Africa. For this study, the objectives are to (i) evaluate the performance of different methods used to recover *Campylobacter* spp. from environmental water samples, (ii) isolate and enumerate *Campylobacter* cells from river water samples, (iii) identify *Campylobacter* spp. in river water samples.

The Bloukrans River was chosen for this study because it is suspected to be contaminated by faecal inputs from the nearby informal settlement without adequate sanitation and untreated/ insufficiently treated effluent from nearby wastewater treatment plants. Firstly, the physicochemical quality of the river water and the presence of faecal contamination were assessed to confirm suitability for *Campylobacter* presence and survival. Then different approaches for sampling, concentrating and recovering *Campylobacter* spp. from river water samples were assessed. The different methods assessed were (i) direct enrichment of water samples without prior concentration, (ii) prior concentration of water samples by centrifugation followed by membrane filtration, and after that, pooling the residue and pellet together and using it for enrichment, (iii) sampling by the Moore Swab technique whereby flowing surface water is filtered through a gauze deployed in the river for 48 hours, followed by enrichment of the gauze. Colony morphology, Gram staining and polymerase chain reaction (PCR) were used to identify and characterise the microorganisms. Results confirm the faecal pollution of the Bloukrans River. This study provides a procedure that is applicable for obtaining a satisfactory quantitative recovery of *Campylobacter* spp. from environmental waters – a critical need for quantitative microbial risk assessment studies.

Taxonomic and trait-based responses of chironomids to pollution in selected urban rivers in the Eastern Cape, South Africa.

Student: MO Osoh
Supervisors: ON Odume and CF Nnadozie
Degree: PhD (Water Resource Science)

Rapid urbanisation occasioned by human population growth and urban development has been identified as one of the greatest threats to lotic freshwater ecosystems (Odume, 2020). The increasing human population and poor urban developmental planning have severe consequences for ecological systems. The proliferation of industries, agricultural advancement, and wastewater treatment activities constitute the most significant causes of urban pollution of freshwater ecosystems worldwide (Wang et al., 2011; McGrane, 2016; Wiederkehr et al., 2020).

Freshwater ecosystems provide crucial ecosystem services, including serving as important sources of habitat to aquatic biota and biogeochemical cycling of nutrients for the existence and well-being of living organisms. However, most freshwater systems in the world are either mismanaged or overexploited, leading to severe deterioration and biodiversity loss of freshwater ecosystems (Akamagwuna, 2021). Consequently, these systems have experienced far greater biodiversity losses than those recorded in terrestrial ecosystems (Dudgeon et al., 2006). Adequate protection, management and maintenance of freshwater ecosystem services are crucial to ensure the continuous and sustainable provision of desired ecosystem services for human well-being and livelihood.

Biomonitoring assesses riverine systems using organisms such as aquatic macroinvertebrates (Edegbene et al., 2021). In South Africa, the South Africa Scoring System version 5 (SASS5) was developed to categorise the water quality of freshwater sites, using the community assemblages of macroinvertebrates (Dickens & Graham, 2002). Although this tool has gained wide application and acceptance and enables the rapid bioassessment of the ecological health of freshwater systems, it is limited by a coarse family taxonomic resolution that ignores the diversity and traits of various biological indicators, such as some diverse macroinvertebrate families.

Macroinvertebrate families, such as Chironomidae, are among the most diverse macroinvertebrate groups inhabiting freshwater ecosystems (Boulaaba et al., 2022). Their ability to survive in natural and degraded water and their diversity makes them an ideal candidate species for biomonitoring impacted urban rivers. Hence, a tool based on the highest taxonomic resolution is imperative for acquiring data specific to solving ecologically relevant questions regarding urban pollution in mobile freshwater systems. This study explores applying chironomids' taxonomic and functional characteristics in assessing cross-scale filters of urban pollution in selected urban rivers in Eastern Cape, South Africa.

Study objectives

1. Develop and use a chironomid-based index to assess water quality deterioration of selected urban riverine systems;
2. Explore the distribution patterns of chironomid traits and ecological preferences in selected urban riverine systems;
3. Develop a trait-based approach for predicting the resilience and vulnerability of chironomids to urban pollution;
4. Analyse the effect of spatial filters on macroinvertebrate assemblage structure at multiple scales.

Progress

To date, I have successfully completed all field data collection, including macroinvertebrates and water sampling. Collected water samples have been successfully analysed for nutrient variables, and data captured in Microsoft Excel Spreadsheet. I am currently undertaking a species-level taxonomic identification of the Chironomidae family.

MO Ososh holding a kick-net for collecting macroinvertebrates in the Bloukrans River during a field sampling campaign.

A mechanistic and trait-based approach to investigating the distribution and effects of microplastics on riverine macroinvertebrates.

Student: EK Owowenu
Supervisors: ON Odume and CF Nnadozie
Degree: PhD (Water Resource Science)

Microplastic pollution (MP) in global aquatic systems is increasingly becoming a concern as it may impact biota such as macroinvertebrates (Windsor et al., 2019). Microplastics (particles <5 mm in diameter) (Akindele et al., 2019; Dahms et al., 2020; Frias & Nash, 2019) have a widespread distribution (Dahms et al., 2020), and a large volume of literature demonstrates several ecological effects (de Sá et al., 2018a). Laboratory and field-based occurrence studies show that the ingestion of microplastic particles can affect aquatic organisms (de Sá et al., 2018a; Issac & Kandasubramanian, 2021; Ma et al., 2019; Scherer et al., 2017), including zooplanktons (Frias et al., 2014), invertebrates (Akindele et al., 2019; Scherer et al., 2017; Welden & Cowie, 2016), fish (Kühn et al., 2020; McNeish et al., 2018; Sequeira et al., 2020) and birds (Lavers et al., 2019). Most of these studies investigated macroinvertebrates (Akindele et al., 2019; de Sá et al., 2018b) because of their overwhelming influence on freshwater ecosystems worldwide. However, the studies were not designed to consider hydraulic habitat distribution/patchiness although hydraulic habitat patchiness influences the distribution of aquatic organisms such as macroinvertebrates (Thomson et al., 2001) and their potential exposure to microplastics. Previous studies have focused more on effect concentrations, polymer identification, and polymer shape and colour categorization (Ockenden et al., 2021; Shen et al., 2021), yet there is no complete scientific understanding of how and what might predispose aquatic organisms to microplastics in their respective habitats.

Although lentic and marine habitats are the most probable ultimate sinks receiving microplastics from rivers with potential adverse effects for benthic invertebrates (Berlino et al., 2021; Hoellein et al., 2019; Tang et al., 2021), rivers can act as both conduits and accumulators of microplastics (Hoellein et al., 2019). Rivers are characterised by different flow environments and hydraulic patterns resulting from the interaction between flow, substrate, and channel morphology. Hydraulic biotopes, which have been used to describe different instream flow environments, are composed of very fast (e.g., rapids) to slow flowing (e.g., pools) patches creating "flush and sink zones". Thus, hydraulic biotopes impact microplastic distribution, creating different microplastic concentrations in each flow patch; a fast-flowing patch becomes a microplastic flush zone; a slow-flowing patch becomes a microplastic sink zone.

Traits mediate organism-environment interaction, that is, a set of traits determines where a species can live (Schmera et al., 2017); traits may provide a rational, mechanistic understanding of species-environment relationships (Verberk et al., 2013). This understanding suggests that macroinvertebrates that select a microplastic flush or sink zone may have a combination of traits that adapt them to such zones and might create differential exposure to microplastics. For example, macroinvertebrates preferring a microplastic sink zone could be potentially more exposed to microplastics than those selecting a flush location. In this regard, traits that mediate between an organism and its environment are key to predicting an organism's response to environmental change and to diagnosing and discriminating between environmental stressors through mechanistically linked traits. Thus, hydraulic biotope distribution/patchiness, traits, and ecological preferences are important biophysical factors critical to understanding the risk posed to macroinvertebrates by microplastics. This study aims to investigate the distribution and effects of microplastics on riverine macroinvertebrates using a mechanistic and trait-based approach. The study is in its second year and is being carried out in two urban rivers: the Swartkops and Buffalo River catchment in the Eastern Cape of South Africa.

Study objectives

1. To characterise the selected sites in terms of land use, water quality variables and hydraulic habitats;
2. To determine the distribution of MP in relation to land use and hydraulic habitat types;
3. To examine macroinvertebrate exposure to MP, based on their preferred hydraulic habitats and traits possessed;
1. To develop a mechanistic framework for predicting macroinvertebrate vulnerability to MP.

Progress

The current study is at the data collection and data analysis stage.

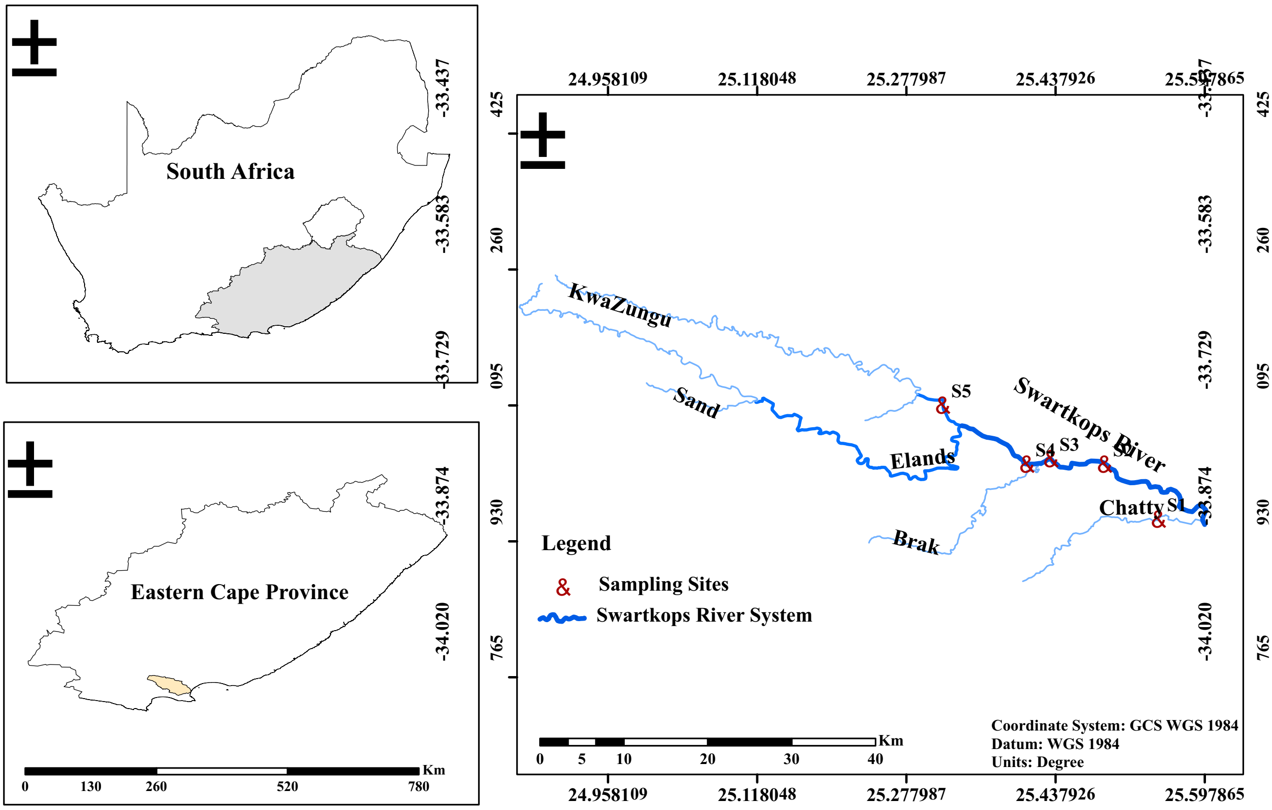


Figure 1. Swartkops River catchment and selected sites

Figure 2: EK Owowenu dissecting macroinvertebrate specimen for microplastic analysis in the Institute for Water Research Water Quality Laboratory

An exploration of the potential contribution of an ethical and value-based approach to water governance challenges in the lower section of the Upper Vaal Catchment, Gauteng, South Africa.

Student: N Tavengwa
Supervisor: NO Odume
Degree: MSc (Water Resource Science)

The Vaal River is the third largest river system in South Africa and is the main source of water for the Gauteng Province. Not only does the Vaal River system significantly contribute to the national Gross Domestic Product (GDP), but it also provides a wide range of important ecosystem services. These include, but are not limited to, freshwater for domestic use, agricultural water, industrial water, space for waste disposal and sites for religious activities. However, because the main tributaries of the Vaal River, including the Klip, Suikerbosrand, and Leeuspruit, drain from a heavily industrialised and urbanised catchment, the water quality of the Vaal River is compromised. Continuing pollution and consequent deterioration of water quality and ecosystem health negatively impact the functioning of the river system and downstream water users. It is necessary to implement appropriate and effective water governance and management practices in order to ensure the sustainability of the Vaal River system.

It has been argued that systemic water governance failure is one of the root causes of the challenges confronting the water sector in South Africa (Goga & Weston, 2015). The Vaal Barrage Catchment, particularly, is subjected to recurring incidents of illegal industrial and raw sewage discharges, all linked to systemic failure of water governance, specifically in the sense that relevant regulations are not being implemented. This situation has ethical implications because supplying polluted water to residents contravenes their '*human right to safe water and an environment that is not harmful to their health*'.

Although many water problems in South Africa have ethical implications, ethics is not sufficiently considered in either water governance practice or research. In order to contribute towards filling this gap, this study explores the potential contribution that an ethics and value-based approach can make towards addressing water governance challenges in the lower section of the Upper Vaal River catchment in Gauteng. The study uses a triangulation approach of data collection involving document analysis, workshops, focus group discussions, key informant interviews, and participatory observation. For theoretical guidance, the study uses the ethical framework recently developed by Odume et al., (2022).

Raw sewage pollution as a result of poor water governance

Overflow of raw sewage caused by failure of Pumping Station 8 in Vereeniging (Photograph by Noleen Tavengwa, 8 October 2021)

Aim of the study

- To explore the potential contribution of an ethical and value-based approach in addressing water governance challenges in the lower section of the Upper Vaal Catchment.

Objectives

- To analyse water governance challenges and their ethical dimensions in the lower section of the Upper Vaal WMA;
- To analyse equity dimensions among key institutional water users within the lower section of the Upper Vaal WMA.

Microplastics as potential vectors for selected organic chemical pollutants in freshwater ecosystems

Student: E Tumwesigye
Supervisors: ON Odume, GW, Nyakairu and CF Nnadozie
Degree: PhD (Water Resource Science)

The sustainability and functionality of freshwater ecosystems worldwide rely on the ecosystem's ecological balance and energy flow through various food webs. These processes are, however, currently under threat by the potential of environmental microplastics (MPs) – diameter-size range 1µm to 5000 µm – to change the fate of chemical contaminants. For this reason, studies on microplastics have attracted more attention as a new type of emerging environmental contaminant. Microplastics exert their ecological and human health impacts through the (in)organic compound contaminants associated with MP particles (additives) and as vectors for pollutants (adsorbed contaminants) in natural waters (de Sá et al., 2018; Cox et al., 2019).

This vector effect of MPs is of particular interest because MP polymers differ in their chemical-physical properties, which leads to the modification of their behaviour and associated contaminants in aquatic ecosystems (Mei et al., 2020), and complicates analysis of the resulting, possibly linked, environmental risk (Ding et al., 2019). Additionally, the vector effect could make MPs act as a back door to the entrance of these contaminants into organisms once they are sorbed in the polymer surface and, ultimately, to humans through the food chain (Waldrop et al., 2016; Pittura et al., 2018).

These plastic materials have different surface characteristics, chemical makeup, carbon chains, functional groups, and crystallinity. The differences in characteristics play a role in how they interact with and potentially act as vectors of the contaminants in the aquatic environment. Depending on the plastic materials, the interaction with contaminants, especially of a chemical nature in the environment, could be hydrophobic, π-π interaction, electrostatic interaction-repulsion, hydrogen bonding, Van der Waals forces, halogen bonding, or partition effect (Luo et al., 2022).

The role of MPs as vectors of environmental contaminants in terrestrial, freshwater systems is of particular interest, given that freshwater systems like rivers are sources of drinking water (although severely polluted by plastics, Figure 1) in too many homesteads around the world. Nevertheless, these areas are becoming an integral source of MPs to coastal and marine environments (Biginagwa. 2016, Gallagher et al., 2016; Hayami & Hamada, 2016; Vendel et al., 2017). Knowledge of the impacts of MPs and their vector role in freshwater environments is still in its infancy (Li et al., 2020) compared to other aquatic environments.

Figure 1: plastics dumped in Bloukrans River system in Eastern Cape, South Africa

This research, therefore, provides insights into the current debate on whether microplastics are significant vectors that pollute the freshwater environment. Two terrestrial river systems in the Eastern Cape, South Africa, were used as study areas for this research (Figures 2 and 3). Previous studies have indicated that the rivers are severally contaminated with organic chemical compounds, specifically pharmaceuticals (Farounbi & Ngqwala, 2020; Vumazonke et al., 2020).

Preliminary Findings

Preliminary findings using a scanning electron microscope (SEM) and energy dispersive spectroscopy - Energy Dispersive X-Ray Analysis (EDX) indicates MPs are vectors. The microphotographs of the retrieved MPs reveal a change in MPs' surface morphology, with EDX analysis showing new elements associated with the retrieved MPs (Figure 4).

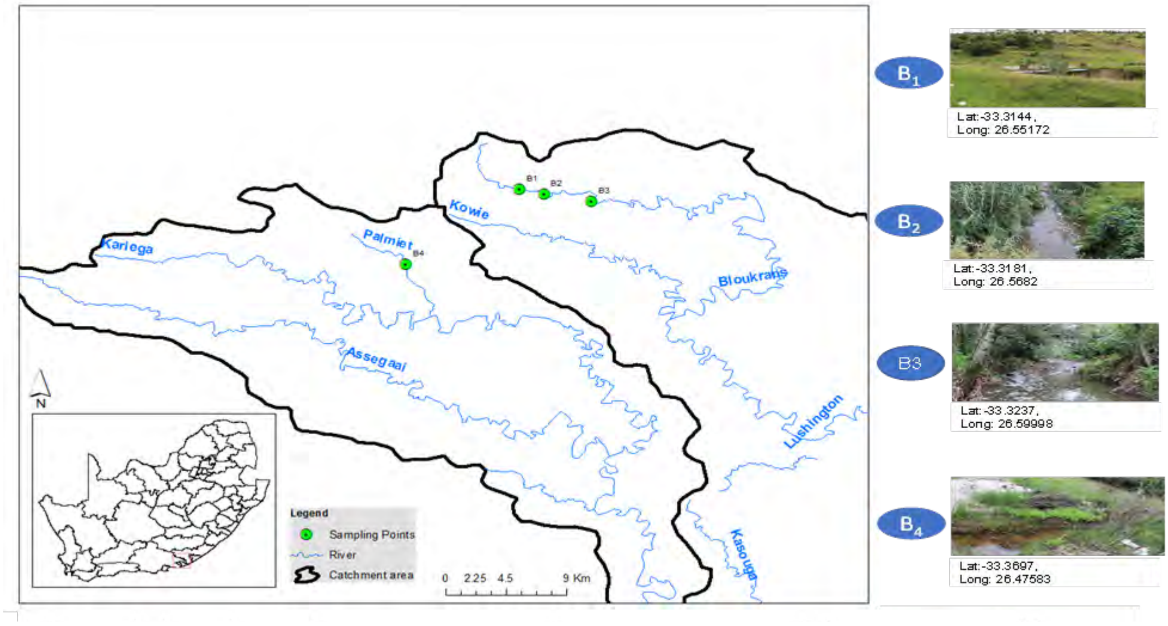


Figure 2: Bloukrans River: land use types B1: Human settlement, B2: WWTP, B3: Agricultural area, B4: Control site

Figure 3: Swartkops River: land use types S1: WWTP, S2: Human settlement, S3: Agricultural area, S4: Control site

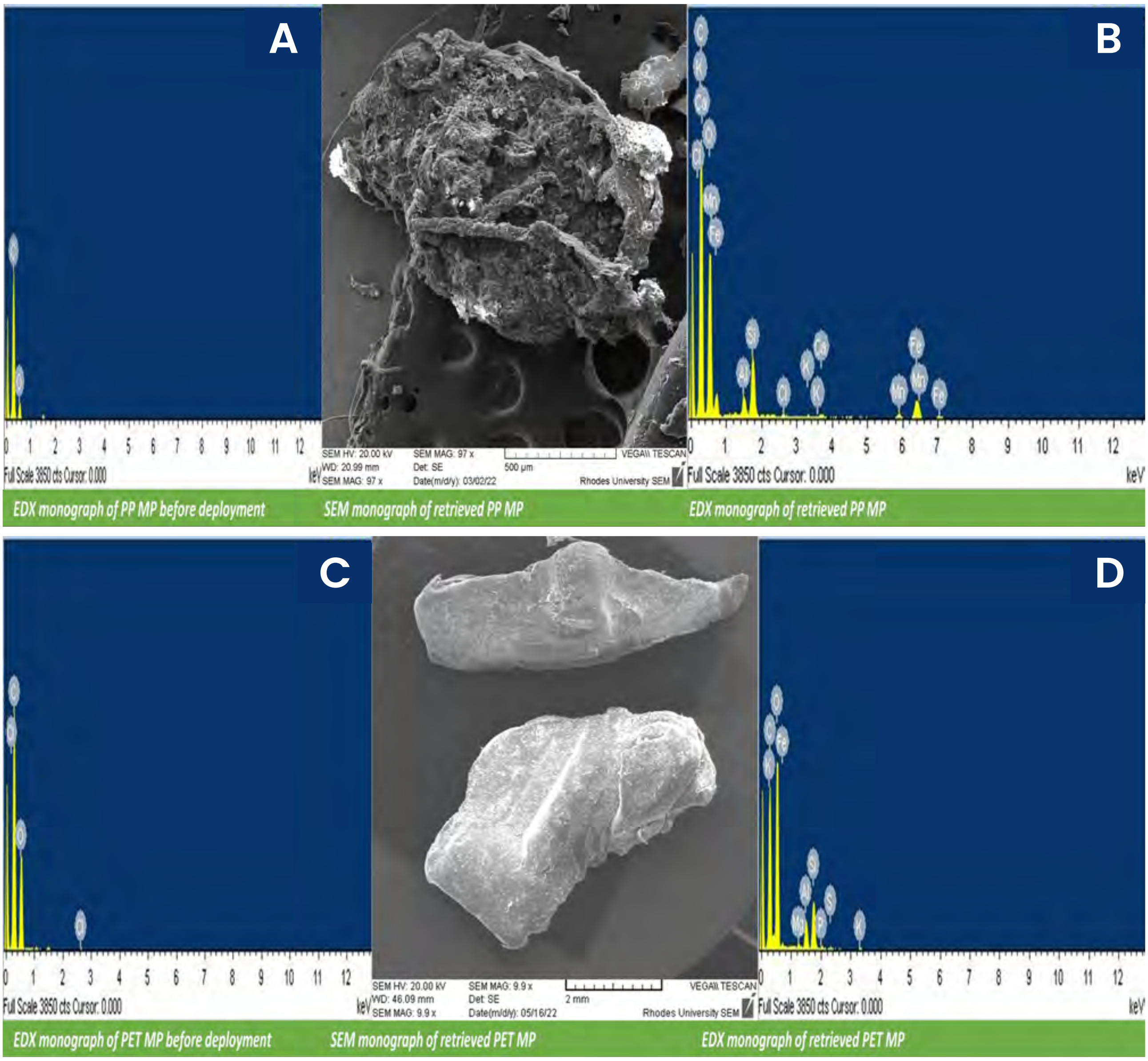


Figure 4: Energy dispersive X-ray-EDX spectrum report. Spectrums A & C are EDX analysis reports of clean PP and PET MPs respectively. Spectrums B & D are the EDX spectrum analysis report for the retrieved PP and PET MPs respectively, indicating the association of new elements on the MPs of K, Mn, Al, Si, Fe, Ca, Cl, an indactor of MPs acting as vectors in freshwater systems.

Adaptive Water Resource Management projects

Unlocking Resilient Benefits from African Water Resources (UKRI Research Excellence Grant)

CG Palmer (Director), JL Tanner (Co-Director / Director from July 2022)

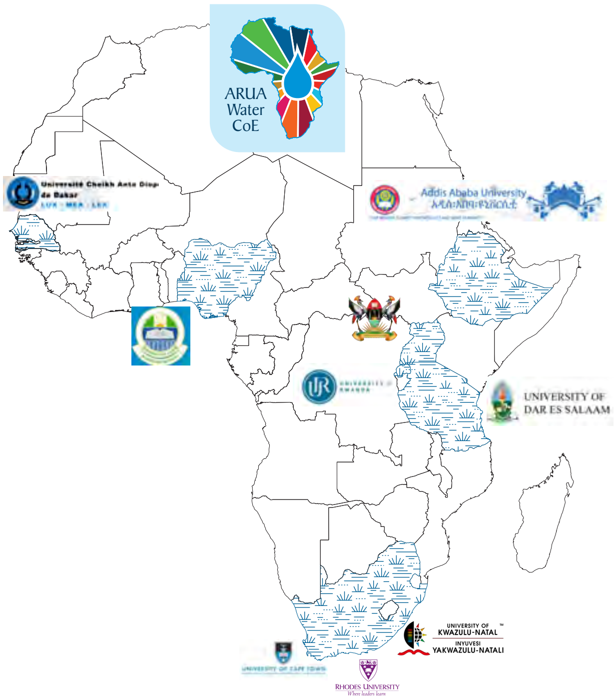
April 2020–December 2023

Sponsor: UKRI-GCRF

Collaborators: Prof. Zerihun Woldu (Addis Ababa University, Ethiopia, Co-Director), Prof. Noble Banadda, Assoc. Prof. Isa Kabenge (Makerere University, Uganda), Prof. Frances Cleaver (Lancaster University, UK), Prof. Serigne Faye (Cheikh Anta Diop University, Senegal), Prof. Ezechiel Longe (University of Lagos, Nigeria), Prof. Joel Nobert (University of Dar es Salaam, Tanzania), Prof. Vanessa Speight (Sheffield University, UK), Dr Nsengimana Venuste (University of Rwanda, Rwanda), Prof. Kevin Winter (University of Cape Town, South Africa), Prof. Seifu Gurmessa (University of KwaZulu-Natal, South Africa)

Project website: https://www.ru.ac.za/iwr/aruacoe/

The African Research Universities Alliance (ARUA) Water CoE is one of four multi-disciplinary and multinational projects addressing the UN's Sustainable Development Goals (SDGs) that are supported by the UKRI-GCRF Research Excellence Grant. The ARUA Water CoE Research Excellence project (also referred to as RESBEN) is titled *Unlocking Resilient Benefits from African Water Resources*. The aim of the project is to apply transformative, transdisciplinary, community-engaged research, to shift water development outcomes towards achieving the SDGs, with the focus on continental water development priorities: water supply and pollution.



Collaborating Universities of the ARUA Water CoE in Africa and their strengths

The project consists of six proposed project Case Studies that exemplify water-related challenges across Africa, and support progress towards SDG6, the core water-related Sustainable Development Goal. In addition to the six Case Studies, there are three South African learning sites (led by the University of KwaZulu-Natal [UKZN], the University of Cape Town [UCT], and Rhodes University) that will provide insights and learning opportunities related to Case Studies. The project team's vision is to change the approach to water development, for Africa, by Africans.

The project objectives are:

1. To apply a novel Adaptive Systemic Approach to six country-based Case Studies that shifts developmental research outcomes towards greater equity and sustainability.
2. To address equitable sharing of water supply benefits arising from contested water use, in three catchment-based Case Studies.
3. To establish the sources, pathways and impact of selected pollutants and to develop community pollution resilience in two city-based Case Studies.
4. To develop participatory governance to support resilient water supply, water quality, and ecosystem protection in all Case Studies.
5. To build an effective, excellent, partnered African water research network.

Project progress

After many months of uncertainty, we received the good news at the end of 2021 that the funding for the 2022/23 year was restored to 100%. Following the news of the budget cuts, we had integrated the work conducted under the two grants to ensure maximum capacity building and supported equitable partnerships within Nodes and external stakeholders. The restrictions due to COVID and the threat of funding cuts and the resulting uncertainty in the short- and long-term have led to the Water CoE Hub team working overtime on adjusting our interactions with the CoE members and stakeholders while still aiming for the Project to have impact in line with our project aims. This has resulted in the Water CoE being ambitious and setting a high density of work through interactions and training. Many researchers in the Water CoE network have acknowledged some fatigue and frustration over the year.

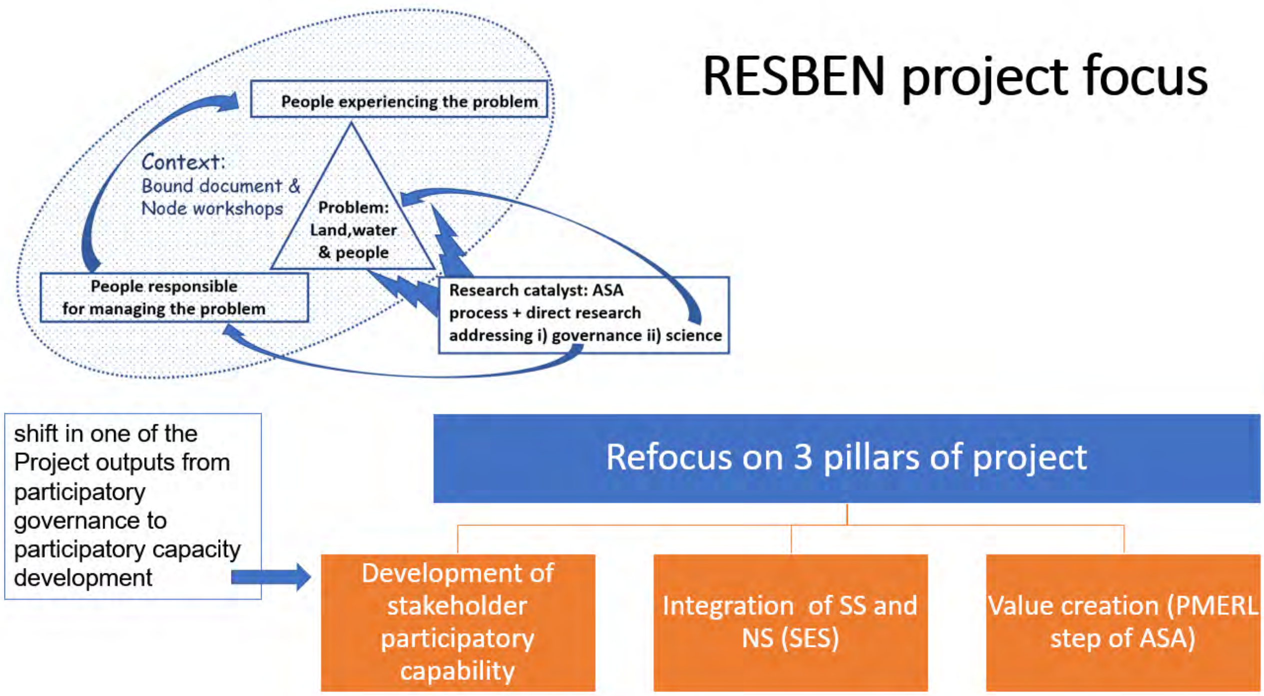
During 2022, we focused on three pillars of CoE strengths: development of stakeholder participatory capability, integration of social science and natural science (social-ecological systems work), and value creation as shown in the adjoining figure. Each node was asked to focus primarily on one of the first two pillars, with support of the Hub postdocs, and the last pillar of Value Creation was led by Dr Matthew Weaver. Dr Bukho Gusha has been working with the Ethiopia node, Dr Rebecca Powell with Tanzania, Dr Notiswa Libala with Nigeria and Rwanda nodes, Dr David Gwapedza and Dr Bezaye Gorfu with the Uganda node, and Dr Rebecka Henricksson with the Senegal node. Sadly, Dr Libala left the Water CoE in July so the support for the Nigeria and Rwanda nodes has been shared by the Hub team.

Prof. Tally Palmer retired at the end of June 2022, and the role of Project PI was transferred from Prof. Tally Palmer to Dr Jane Tanner, who was the co-Director up until that time. This change was approved by the Project Board and has been supported by all the Nodes. Prof. Palmer has continued to remain involved, while Dr Tanner has taken on a stronger role in the Water CoE.

Learnings in an Adaptive Planning Process (APP) Debrief Session and additional APP workshops

This event was held online in May 2022 with the CoE nodes, and it was facilitated by Dr Matthew Weaver, Dr Rebecka Henriksson, Dr Notiswa Libala and Ms Margaret Wolff. The aim of the workshop was to learn from the experience and challenges faced in the four countries where APP workshops were held before January 2022. This helped the Hub team and other nodes who had not run their own APP workshop to plan their workshop and engagement better. Following this debrief session, Ethiopia, Uganda and the University of Cape Town have successfully run their own workshops.

For the Ethiopian APP workshop, Drs Bukho Gusha and Matthew Weaver supported Addis Ababa University and Water and Land Research Centre (WLRC) in facilitating the workshop with stakeholders from two learning watersheds in the Amare Region. The engagement was hosted over two days. On the first day, farmers, watershed management officials and religious leaders participated in a watershed learning exchange. The exchange was facilitated by the WLRC. On the second day, additional government officials were also present for the APP workshop. Facilitated in the local Amharic language, the workshop yielded positive engagement where



The three pillars of Node strengths which has been used to conduct planning and the way forward for 2022/23 year. Each Node has adapted this plan for their own Node.

farmers, religious leaders, government officials and academics shared experiences, listened, and learnt from one another as they engaged in collective vision and objective setting. The Ugandan node also held an APP workshop in early August which was supported by Dr David Gwapedza and Ms Naledi Chere (from UCT node).

Node representatives who shared their experience of running APP workshops in their node country

Attendees of Uganda APP workshop held in early August 2022

The following **brochure** was created to introduce the Water CoE to new and potential partners.

ARUA Water CoE

SDG 4: Quality Education

SDG 6: Clean Water and Sanitation

SDG 13: Climate Action

SDG 15: Life on Land

SDG 16: Peace, Justice and Strong Institutions

The African Research Universities Alliance (ARUA) Water CoE, currently funded by UKRI:GCRF, aims to be a centre for innovative and progressive research, which focuses on the **African response to the Sustainable Development Goals (SDGs)**. Water plays a vital role in ensuring equitable, stable and productive societies and functional ecosystems. Hence, the United Nations recognised ensuring sustainable management of water and sanitation as one of the seenteen sustainable development goals (SDGs) (i.e. Goal 6). The CoE recognises that **water is the key thread and catalyst to realising the remaining sixteen SDGs in Africa.** https://www.ru.ac.za/iwr/aruacoe/about/

The ARUA Water CoE has been awarded two UKRI GCRF grants:

A) Capacity Building Grant 'Water for African SDGs' aims to establish and develop the ARUA Water CoE as an effective, high-performance, hub and network of 8 African Universities' researchers and post-graduate students.

B) Research Excellence Grant 'Unlocking Resilient Benefits from African Water Resources' brings together partners from six universities across Africa, three universities in South Africa and two UK Universities to collaborate on research that addresses SDG6: Sustainable water and sanitation for all.

ADAPTIVE SYSTEMIC APPROACH

GCRF

UK Research and Innovation

Partnerships

The Institute for Water Research (IWR) at Rhodes University is the Hub of the Water CoE. The IWR aims to contribute to the knowledge of and promote the understanding and wise use of natural water resources in southern Africa.

Ethiopia: The Water & Land Resource Centre at Addis Ababa University specialises in natural resource management, restoration and development research. The node has an established catchment learning site, focussed on reducing the loss of fertile soil, and vegetation restoration.

Nigeria: University of Lagos CoE partners specialise in water quality including the fate and transfer of contaminants in surface and groundwater. The research focuses on Lagos City with the aim to identify factors that exacerbate contamination exposure, and co-develop participatory governance capacity.

Rwanda: University of Rwanda CoE partners lead the NEPAD Centre of Excellence in Biodiversity and Natural Resources Management (CoEB) specialising in aquatic ecology, applied entomology and conservation. The node team is working on Akagera River (Akagera National Park) and considering benefits to local people from protected areas.

Senegal: Cheikh Anta Diop University CoE partner specialises in applied hydrology and Integrated Water Resource Management. The node is working on the transboundary Senegal River basin and aims to foster actions towards i) efficient water use; ii) water resource and ecosystem protection; and iii) mediation of water conflicts and promotion of family farms.

Tanzania: University of Dar es Salaam CoE partners are hydrologists with extensive surface water modelling experience. Other expertise includes hydro-dynamics, geohydrology, remote sensing, environmental change and Integrated Water Resource Management. The node is working in the Rufiji River Basin with the aim to engage with water contestation and the value of the natural resource to local people.

Uganda: Makerere University CoE partners are water quality and pollution control specialists, with skills across agricultural & biosystems engineering, climate change, hydrology, remote-sensing, evapotranspiration, water quality and Integrated Water Resource Management. The research focus on Kampala City aims to profile pollution levels, sources and fate of pollutants in order to engage creatively to promote sustainability.

South Africa: University of Cape Town CoE partners bring expertise in urban water management, and includes the team from the Future Water Institute. University of KwaZulu Natal, Centre for Water Resources Research specialises in physical and social hydrology. The two South African learning sites are supporting the other African nodes.

Two UK partners:

University of Sheffield CoE partners bring expertise in Civil Engineering and Structural Engineering (water quality and integrated urban water systems).

Lancaster University CoE partners bring expertise in water governance, natural resource management and gendered livelihoods.

RESBEN brochure that highlights the work and outputs of the Research Excellence grant

Water for African SDGs (UKRI Capacity Building Grant)

CG Palmer (Director), JL Tanner (Co-Director; Director since July 2022)
September 2019–August 2022

Sponsor: UKRI-GCRF
Collaborators: Prof. Zerihun Woldu (Addis Ababa University, Ethiopia, Co-Director), Prof. Noble Banadda, Assoc. Prof. Isa Kabenge (Makerere University, Uganda), Prof. Serigne Faye (Cheikh Anta Diop University, Senegal), Prof. Ezechiel Longe (University of Lagos, Nigeria), Prof. Joel Nobert (Dar es Salaam University, Tanzania), Dr Nsengimana Venuste (University of Rwanda, Rwanda), Prof. Kevin Winter (University of Cape Town, South Africa), Prof. Seifu Gurmessa (University of KwaZulu-Natal, South Africa)

Project website: https://www.ru.ac.za/iwr/aruacoe/

The ARUA-UKRI research programme Capacity Building Grant supports the Water CoE project, *Water for African SDGs*. The aim of the project is to establish and develop the ARUA Water CoE as an effective, high-performance hub and network of the researchers and postgraduate students from nine African universities. The CoE plans to use research to catalyse change towards social and ecological justice and sustainability, paying attention to the African community water and sanitation needs. The project team brings together diverse strengths in the area of water, so the nodes can flexibly link and innovatively respond to research funding calls, and effectively apply research.

The project objectives are:

1. Create a Community of Practice (CoP) of African scholars, particularly Early Career Researchers (ECRs), conversant with water resources management in relation to the SDGs, with a complex social-ecological systems lens.
2. Provide African scholars, particularly ECRs, with exposure to international facilities and scholars.
3. Provide support for scholarly performance, for example, through publications and project proposals which are closely linked with the Research Excellence grant, and through postdoc support of writing.

After the funding cuts, the two funded projects (under the Capacity Building and Research Excellence grants) were fully integrated and the Water CoE had to adjust the planned activities as there was no guarantee, until late in 2021, of continued funding for the year 2022/23. This resulted in significant time spent re-planning methods and budget and some chaotic planning of activities and uncertainty about deliverables by the CoE Nodes.

Strategic Adaptive Management (SAM) Training of Trainers Workshop – June 2022

The SAM training workshop was designed to build participants' understanding of the methodology and practical facilitation process of running a SAM workshop. The workshop was facilitated in a blended (face-to-face and online) format. Each session was designed to maximise inclusivity and fair participation of all participants (both online and in-person). Achieving this inclusivity, particularly with the intention of not alienating the online participants, was a challenge. With the help of smart audio and video technology, and a dedicated technical team led by Mr David Forsyth, we ensured that no one was left behind.

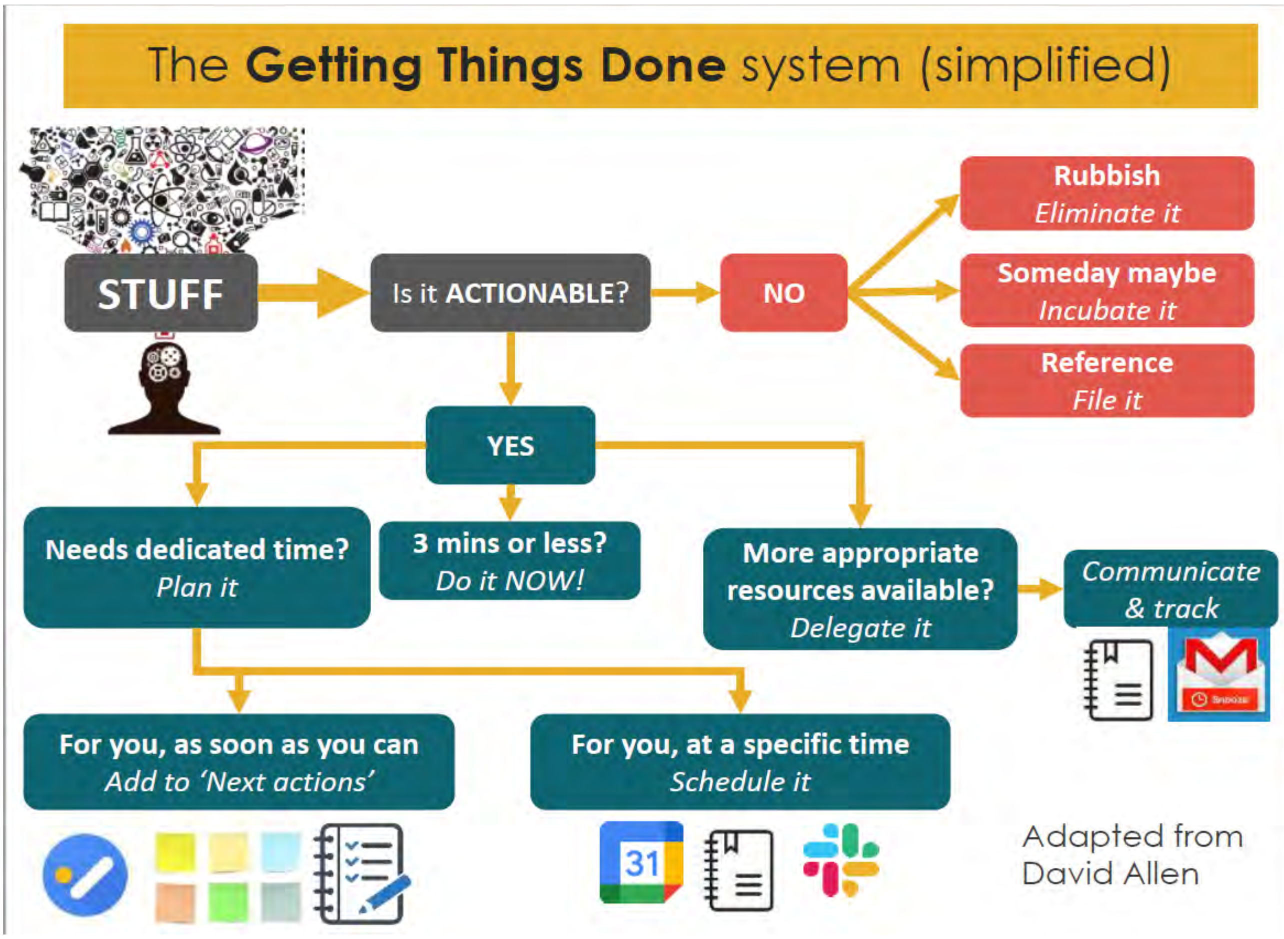
Publications, proposals and writing support

The Hub team set aside three weeks during March, May, September 2022 to meet in person and focus on furthering the publications that the Hub team is leading or working with node research assistants. These weeks involved sharing techniques and challenges and the weeks were particularly helpful for the postdocs in developing a community of practice. Lucy O'Keeffe was brought in for one afternoon during the writing weeks to run an organisational workshop for individuals to evaluate their productivity styles (primarily as prioritisers, planners, arrangers or visualisers, or something in between) in order for individuals to figure out the best way to move ahead and get work accomplished. In addition to these three weeks, the team meets online on Monday afternoons to share progress and encourage work. The team is currently working on 14 papers, two or which have recently been published.

We have also been working on proposals with various collaborators. Dr Tanner submitted a proposal under the call for Climate Adaptation and Resilience (CLARE) - Smaller Grants, which was unfortunately not successful. At present, we are working on the Water4All proposal led by our French partner, Dr Olivier Barreteau at INRAE. This proposal was submitted in early November.

Participants at the ARUA Water CoE Strategic Adaptive Planning Training of Trainers workshop held at Rhodes University in June 2022

Some of the online participants of the SAM workshop in June 2022



One of the slides from Lucy O'Keeffe's presentation to help the Hub team attendees focus on the tasks

Conferences

A contingent of ARUA Water CoE members attended two conferences in October. Water CoE Director, Dr Jane Tanner was invited to give a keynote address at the inaugural South African Hydrology Society (SAHS) conference held in Johannesburg from 10–12 October 2022. Her inspiring talk focused on integrating society into hydrology and the related challenges. Research Assistants from the Water CoE node universities were given the opportunity to attend the conference as part of the CoE's capacity-building effort. Mr Gyaviira Ssewankambo, based in Uganda, presented his research and won the best oral presentation at the conference. Our hearty congratulations to him and his supervisors, including Dr David Gwapedza!

Six members of the ARUA Water CoE presented at the Garden Route Interface and Networking (GRIN) meeting held in Sedgefield from 11 to 13 October 2022. This networking meeting is held annually and provides a forum for researchers and practitioners interested in understanding and managing (navigating) social-ecological systems and their complex interactions and feedbacks. The Adaptive Systemic Approach (ASA) framing the UKRI-funded Unlocking Resilient Benefits from African water resources (RESBEN) project, was given its own session on Day 2 of the meeting.

In the ASA-RESBEN Session, Professor Tally Palmer presented an overview of how the Adaptive Systemic Approach emerged from more than a decade of collaborative research. Margaret Wolff presented a sliver of the Adaptive Planning Process workshop which forms an integral part of the Adaptive Systemic Approach. Dr Matthew Weaver unpacked the use of the Value Creation Framework by the RESBEN project to illustrate the value for participants as they engaged in the social learning spaces in the project. Dr Rebecka Henriksson from UKZN discussed the significance of integration between disciplines (e.g., natural science and social science), methods and data sources, and between academic and non-academic knowledge across the project and, in particular, stressed the importance within a CSES and sustainability science framing. Finally, Dr Ana Porroche-Escudero from Lancaster University challenged the meeting to think about the continuing 'divide' between funding and research in the Global North and Global South. She spoke about the past, existing and continuing institutional structural inequalities that persist in an African context and between Africa and the Global North.

IWR/ARUA Water CoE delegates attending the inaugural SAHS conference in Johannesburg

Brochure

The following brochure was developed to share the work being conducted under the grant.

ARUA Water CoE

SDG 4: Quality Education

SDG 6: Clean Water and Sanitation

SDG 13: Climate Action

SDG 15: Life on Land

SDG 16: Peace, Justice and Strong Institutions

GCRF

UK Research and Innovation

https://www.ru.ac.za/iwr/aruacoe/about/

The African Research Universities Alliance (ARUA) Water CoE, currently funded by UKRI:GCRF, aims to be a centre for innovative and progressive research, which focuses on the **African response to the Sustainable Development Goals (SDGs)**. The CoE recognises that water is the key thread and catalyst to realising the remaining sixteen SDGs in Africa. The UKRI GCRF **Capacity Building Grant 'Water for African SDGs'** aims to establish and develop the ARUA Water CoE as an effective, high-performance, hub and network of 8 African Universities' researchers and postgraduate students.

The Theory of Change diagram for this grant focuses on three main outputs as contribution to SDG 6 on improved water resources management, availability and sanitation.

Output 1. Activities for Early Career Researcher Capacity Building

a) **Digital Storytelling videos:** One Early Career Researcher (ECR) from each African node attended a weeklong course in creating digital stories. Each participant's video highlighted on-going issues and node's research. The videos were launched at the Third ARUA Biennial Conference to showcase how digital storytelling can enhance science communication (watch them on our youtube channel (https://www.youtube.com/watch?v=e8fCNAvWNSQ)

b) **Facilitating Social Learning Training of Trainers course:** One ECR / Research Assistant (RA) from each African Node attended this 3-month course to build skills in stakeholder engagement.

"Training of Trainers"

Rhodes University

c) **Social Science Methods Group:** has built capacity of RAs on qualitative research methodology and theories about power in relation to water governance.

Output 2. Publications

a) **Writing Community of Practice (CoP):** aimed to develop journal articles that are led by RAs who are registered for postgraduate degrees.

b) **Data Management and Analysis course:** complemented the Writing CoP through building skills using R programming language.

ARUA WRITING COMMUNITY OF PRACTICE

Structured support for your academic writing journey

ARUA-RESBEN course

Output 3. Grant proposals and Collaborative projects

a) **Grant proposals:** We are working closely with the N8 UK Universities and as part of other consortia to develop proposals and identify opportunities for collaboration.

b) **Facilitation of an Adaptive Planning Process (APP) and Strategic Adaptive Management (SAM):** Two Training of Trainers workshops have been held at Rhodes University as blended events. The aim of these workshops has been on training in the practical methodology of planning and facilitating stakeholder engagement processes in the node countries.

University of Dar es Salaam

Rhodes University

UK Research and Innovation

GCRF

Brochure that highlights the work and outputs of the Capacity Building grant

Integration workshop

The Hub team spent an enormous amount of time and energy this year planning for what is titled an "Integration Workshop", with the overarching aim being to reflect on how practising the ASA has contributed to the frontiers of sustainability science. The workshop was to be held in Kampala, Uganda hosted by the CoE co-Director, Dr Isa Kabenge, and the node Co-Investigators and social science supervisors were invited to attend for five full days of reflection and planning. The workshop was envisioned to focus on the following five areas:

1. What has our contribution been in relation to the intellectual landscape?
2. Reflecting on the practical realities of applying ASA.
3. The specific ways we have made our contribution in the nodes and the hub through the ASA process, and by recording progress using Value Creation.
4. How are we going to take what we have learned and achieved into refining the rest of our stakeholder engagement and SES integration?
5. Looking to the future, how to continue practising and thinking about concept notes and proposals to build on the work that has been done.

However, six days before the Hub team was to travel to Uganda, full lockdown was declared for two districts in Uganda due to an Ebola breakout. Following much discussion and thought, the CoE decided to postpone the Integration Meeting until the Ebola crisis has stabilised. We hope to reconvene this meeting in early 2023.

Towards meaningful participatory governance in the Tsitsa River Catchment, South Africa: unearthing leverage points in a complex system

Student: AS Fry
Supervisors: CG Palmer and JK Clifford-Holmes
Degree: PhD (Water Resource Science)

It has been almost 30 years since South Africa underwent the renowned transition out of the apartheid regime into a representative multiracial democracy. While there has been notable progress in many developmental aspects of South African society, many inherited dilemmas which persist, as well as a myriad of emerging ones. In the realm of land and water governance, the nascent institutions do not reflect the visions laid out in the pioneering and substantive legislation, policies, and guidelines generated in the post-1994 period. Unaddressed dilemmas include increasingly widespread failures in local water governance, persistent inequality of access to land and water resources, poor or non-existent service delivery in rural areas, underdeveloped institutions for integrated and inclusive water resource management, and the pernicious divisions between the institutions for water resource management and the ones for water service provision. Overcoming these challenges, embedded within complex social-ecological systems across South Africa, will require diverse actors from different levels and sectors of society coming together, working together, persevering together.

So how do we bring diverse actors together to collaborate and participate in ways that are not tyrannical, tokenistic, or manipulative? How do we build institutions for participation which make sense within the broader political system as well as in the lives of people living in the most rural areas? How do we support institutions which meaningfully include diverse voices and enable tangible development outcomes? I explored these questions as part of the transdisciplinary Tsitsa Project, an innovative landscape management project working in the Tsitsa River Catchment (TsRC) in the rural parts of the Eastern Cape. The area's valuable water resources, severe ecosystem degradation and impoverished population make it a valuable site for external investment, research, and innovative efforts towards systemic development.

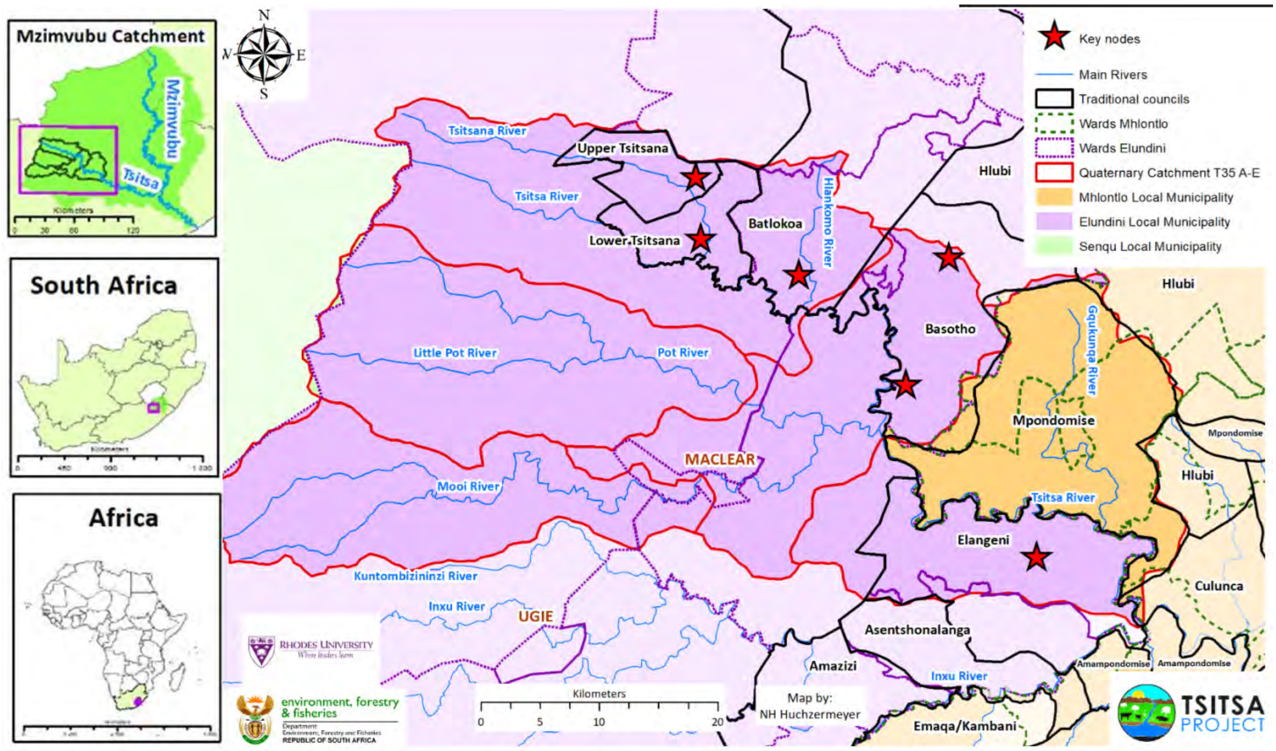
Firstly, I mapped the connections between actors and institutions at multiple levels of governance (from village to national) which influence land and water governance in the TsRC. Secondly, through an in-depth systemic analysis of participatory governance, I analysed my own observations and experiences as an action researcher in relation to those of local governance actors. Finally, I used the body of findings to elucidate five potentially high-leverage points – places in the system which, if engaged, could enable interventions directed at supporting participatory governance institutions to have more sustained impacts.

Governance manifestations observed and analysed in my research align with existing descriptions of the unaddressed fractures and associated dilemmas across South Africa; with the added complexities of being a rural landscape in which democratic and traditional governance systems overlap and interact – constructively and destructively. The findings point to the need for local initiatives which can endure the broader instability and dysfunction. While there is evidence of emergent instances of meaningful participation in the TsRC, the dominant systemic structures create a range of vicious feedback loops and perverse incentives which thwart the promotion of meaningful participation. Interventions must aim towards generating trust and shared understanding while building on more practical and understandable interventions which provide tangible outcomes, enable in-practice capacity development, and provide platforms for all actors to experience and practice meaningful participation together.

I draw on the well-developed fields of adaptive governance and complex social-ecological systems research. My research follows critiques of these fields which suggest that there is still limited consideration of the social aspects which are fundamental driving forces of system functioning – such as power, values and meaning. In particular, my research attempts to deepen the understanding of the 'meaning' and 'meaningful participatory governance' within land and water governance. Meaning which is context dependent as well as generated and diffused relationally among individuals, groups, and societies and thus leads us to ask: meaningful to whom, in what ways, for what reasons? I hope to unearth lessons that one small rural catchment may hold for participation in the governance of rural landscapes and participation in complex, contested land and water governance contexts more broadly.

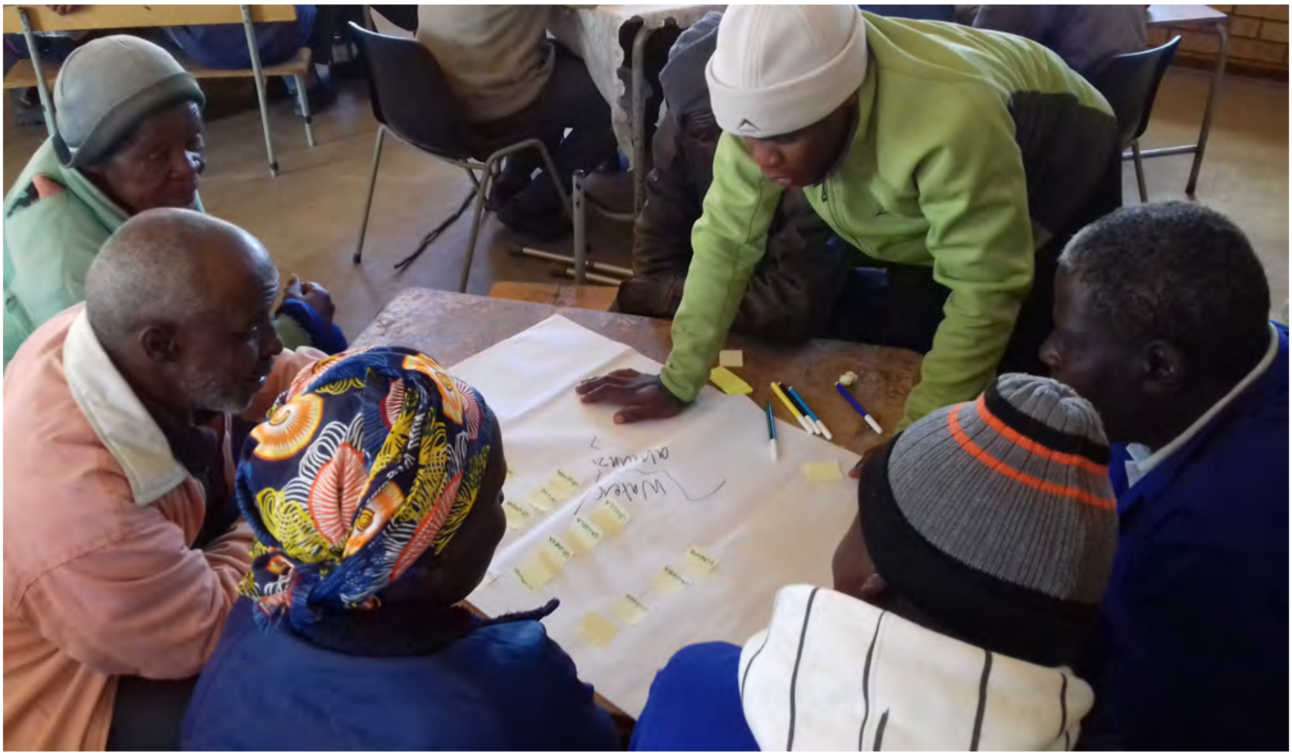
The catchments in which we live will either be protected and integral to social-ecological flourishing, or they will become degraded, polluted, and unusable. In South Africa, our rivers bear a heavy burden of the increasing population and deteriorating infrastructure. Every catchment needs stewards – people who live in them, share them and care for them. These social-ecological stewards must connect with actors across boundaries and meaningfully convene diverse actors in ways which influence the actions of communities and the decisions made within formal realms of governance. My research journey has burdened me with the knowledge of these challenges and their intractability, while simultaneously motivating me through exposure to the emerging stewards who have, with commitment and creativity, taken responsibility for catchments across South Africa.

Sunset in the upper catchment. Remnants of a maize crop in the foreground. Scattered settlements and invasive alien plant stands on the hillsides. Three Sisters rock formation on the skyline. Photo: Anthony Fry.



The ecological and socio-institutional boundaries which fracture the Tsitsa River Catchment into pieces which need to be managed collaboratively by diverse actors as the highly interconnected system that it is. 'Key nodes' refers to the Tsitsa Project's research nodes – the research focus is on the areas where traditional and democratic systems overlap.

Working together – implementer, traditional leader, researcher. From left to right, Chris Jackson (LIMA rural development foundation), Nkosi Moshoeshoe (Basotho Traditional Council), Anthony Fry (Rhodes University). Photo: Nosiseko Mtati.



Former Tsitsa Project Community Liaison Officer, Mzekelo Masiso co-facilitating a workshop in Ntatyaneni Village. Mzekelo left the Tsitsa Project to become the ward councillor embedded within the local municipality. Photo: Anthony Fry.

Exploring effective capacity development and learning processes for citizen science tools for monitoring and sustainable use of springs

Student: T Mazibuko
Supervisor: M Weaver
Degree: BSc (Honours)

Sponsor: Water Research Commission

In South Africa, many communities still rely on raw water sources for domestic use and subsistence farming purposes. The Eastern Cape Province, with the highest unemployment and poverty rate, is South Africa's poorest province and has extensive issues related to water scarcity. As a result, some communities depend on springs, rivers, and other raw water resources. Protecting these water sources is hindered by the lack of tools that the local residents can use for monitoring, protection, and management.

My research is based on two study catchments in the Eastern Cape: a rural catchment, the Tsitsa River catchment, and an urban catchment around the city of Makhanda. The aim of this paper is to explore effective learning and capacity development processes for citizen science tools in monitoring and sustainable use of the springs. The objectives that guided the data collection process of this paper are, i) to investigate the successes and challenges of previous or current learning and capacity development processes for citizen science in water management; ii) to explore stakeholders' previous experiences and preferences for learning, and capacity development processes for citizen science in water management; and iii) to develop guiding principles for the design of effective learning and capacity development processes for citizen science tools in monitoring and the sustainable use of springs.

The two communities that this study focuses on have springs that serve as a water source. For the rural community in the Tsitsa River Catchment area, the springs are their only water source, and these springs are constantly disturbed by livestock and polluted by dumping sites near the springs. The community showed much interest in learning about citizen science tools to protect their springs to ensure an adequate supply of clean and safe drinking water. They were more than happy to participate in a learning and capacity development process to build on their capacity and capabilities to ensure that they are well equipped to efficiently use the citizen science tools.

The community in Makhanda does not make regular use of the spring in their area; they may not use it at all because they have piped water and store water in tanks in the case of water cuts. Despite their minimal to no use of the spring, they were willing to learn about the citizen science tools and take part in a learning and capacity development processes to help manage the spring, a resource which is mostly threatened by pollution.

Thembalami Mazibuko assessing a spring in the Tsitsa River Catchment Area

Understanding ecological infrastructure in relation to people in the Tsitsa River catchment, Eastern Cape, South Africa

Student: AK Ntshangase
Supervisors: M Weaver and CG Palmer
Degree: MSc (Water Resource Science)

We live in a social-ecological world where societies are embedded in the biophysical world and interact with the environment. These interactions are shaped by and relate to each other as they are connected to human values, beliefs, morals, management institutions, indigenous knowledge, and rules that determine how society interacts with the environment. In such a social-ecological system, it is important to explore and understand the variables and relationships within and between each system as this understanding assists in evaluating how systems work and how best to equitably sustain them.

The Tsitsa River catchment suffers from extensive land degradation the detrimental effects of which have deteriorated the ecological infrastructure in the catchment: soils, rivers, wetlands, grasslands, and indigenous forests. This degraded ecological infrastructure has reduced the quality and quantity of the ecosystem services it produces, affecting community livelihoods dependent upon them. In most rural areas, communities depend on the ecological infrastructure within their areas for their well-being and their livelihoods. It is in these very areas where the risk of impairment of ecological infrastructure is greatest. Therefore, a better understanding of the relationship between humans and nature is crucial. This study explores the human-nature relationship in the complex social-ecological system of the Tsitsa River catchment.

The study aims to link an integrated biophysical understanding of ecological infrastructure with insights into social perspectives on the value of the ecological infrastructure in the Tsitsa River catchment. The objectives of the study are threefold: i) to integrate the knowledge of the biophysical functioning of the Tsitsa River catchment based on the Tsitsa Project research (2014–2020) into a narrative of catchment processes, ii) to link the biophysical understanding of the Tsitsa River catchment to the ways catchment residents interact with ecological infrastructure, and iii) since this project is embedded within the SANBI Living Catchment Project, to relate the insights and knowledge from the Tsitsa River catchment about the relationship between people and ecological infrastructure to the goals of the SANBI Living Catchment Project.

A heuristic of rivers as a key ecological element explored in the study (Figure 1) demonstrates the interrelationship between people and ecological infrastructure in the Tsitsa River catchment.

Rainfall is the driver of the hydrology of rivers, and it dictates the amount of discharge. Streamflow velocity and discharge describe the hydrology. Geomorphic processes shape the channel of a river and create aquatic and riparian ecosystems. Geomorphic processes determine the material from which the channel flows, the shape of the channel, and the stability of the riverbeds and banks. River channel characteristics change between reaches. Reaches, therefore, differ in bed material, streamflow, and in aquatic and riparian ecosystems. Water quality determines the ecological health of rivers and is influenced by both natural and anthropogenic characteristics and processes. Sediments in rivers influence water quality. Sediments are transported by surface runoff and baseflow and have both positive and negative consequences on the riverine ecosystems. Macroinvertebrates are usually used to monitor river ecosystem health as they have a range of family-related sensitivities and thus respond differently to river modifications.

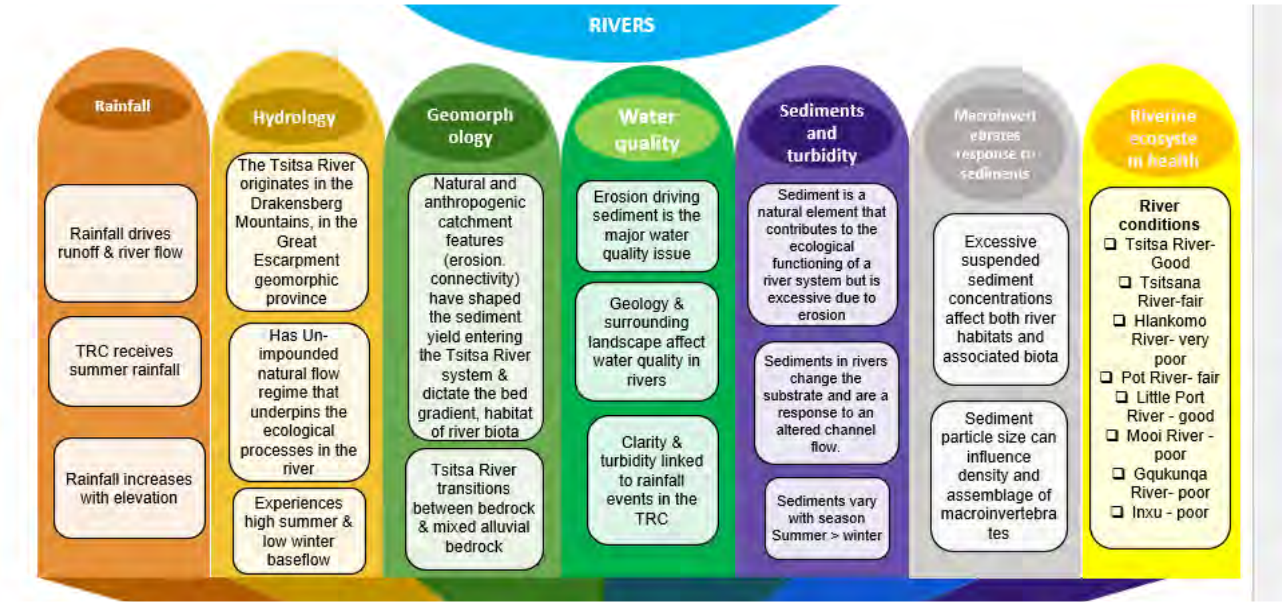


Figure 1: Summary diagram of the functioning of rivers in the TRC.

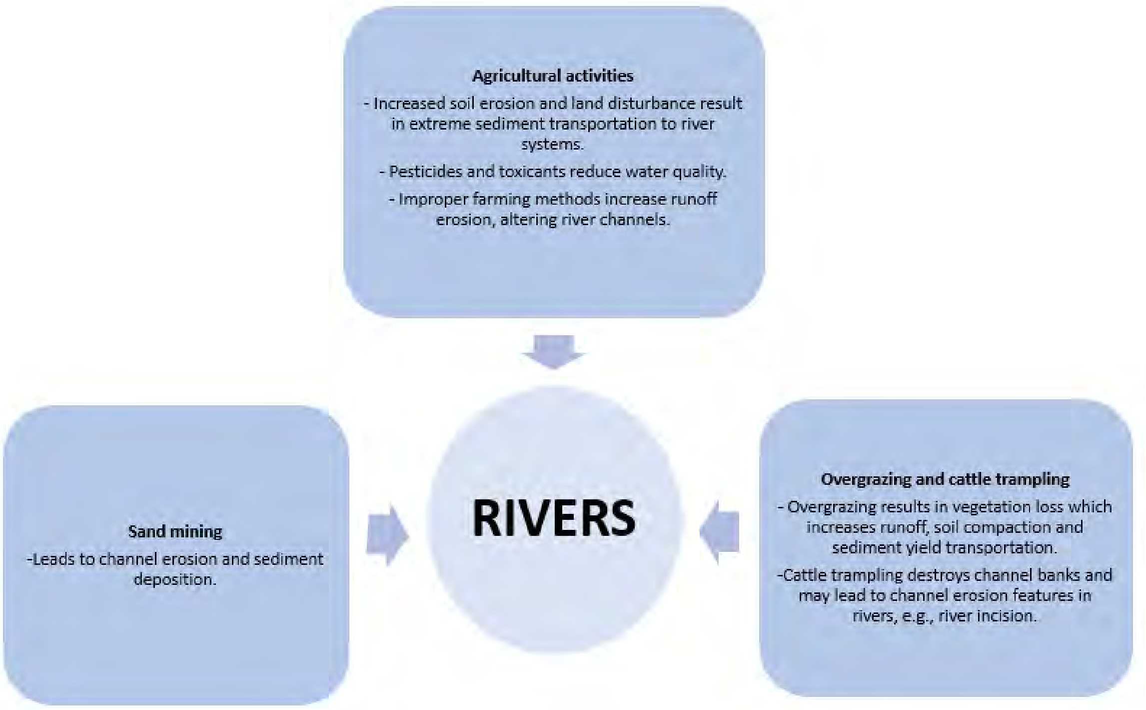


Figure 2: Diagram of human-induced impacts relating to the functioning of rivers in the TRC

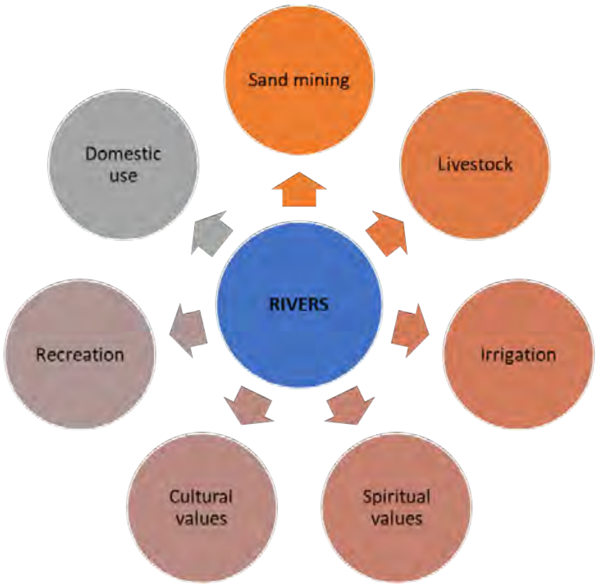


Figure 3: Local community interactions with rivers in the TRC

Miss A Ntshangase presenting at the LaRSSA conference

Exploring the nature and meaning of participation in engaged land restoration project: a question of epistemic injustice

Student: MM Ralekhetla
Supervisors: CG Palmer, L Kelland and SA Paphitis
Degree: PhD (Water Resource Science)

Introduction and background

The increasing loss of natural resources, especially in developing countries, has raised growing concern because it threatens the entire ecosystem and the livelihoods of the people who depend on them. The recognition of the increased pressure and dependence on natural resources has led to the need to manage resources in ways that involve diverse knowledge types and interests by engaging different stakeholders other than government and conservation ecologists.

Managing both biophysical and social components together may be challenging due to the multiple and complex interactions among the different components, which happen at different scales in relation to time and space, and need a proper framing in order to manage (Jahn et al., 2005). An understanding and adoption of complex social-ecological systems (CSESs) to managing natural resources can improve the efficiency of management decisions in the context of natural resource management (NRM) in dealing with the multiple interactions (Cilliers et al., 2013; Ison, 2010) by their very nature, complex and that both scientists and managers in this broad field will benefit from a theoretical understanding of complex systems. It starts off by presenting the core features of a view of complexity that not only deals with the limits to our understanding, but also points toward a responsible and motivating position. Everything we do involves explicit or implicit modeling, and as we can never have comprehensive access to any complex system, we need to be aware both of what we leave out as we model and of the implications of the choice of our modeling framework. One vantage point is never sufficient, as complexity necessarily implies that multiple (independent. To translate the management of CSESs into practice requires different sectors of society to interact with government-appointed resource managers in new ways over time in order to reach a deeper understanding of the system (Berkes, 2009; Olsson et al., 2004). This new way of managing and governing resources has led to the emergence of communities of learning made up of indigenous or local citizens, academics, and managers (Robson et al., 2009). Participation plays a significant role at the interfaces to facilitate the relationships among the actors involved, and the concept of participation plays a central role at the interface that fosters the interactions among the people who are involved in managing a CSES (Turton et al., 2007). However, the concept of participation is a multi-faceted word used to refer to different things.

There is a pervasive tendency to homogenise communities and fail to recognise the individual differences existing within them (Jewkes et al., 1995; Li, 2017). Any group of people includes a range of backgrounds, and therefore different interests and values in relation to, for instance, what participation means (Moen, 2006). If proper care is not taken to unpack these differences, then participation may remain just an ideal instead of a reality (Cornwall, 2008; Cornwall, 2017). I am interested in the experiences of this interaction from the perspective of the stakeholders who engage in it, as a way to find out thick accounts (Geertz, 1973) or more detailed explanations of structures, processes, and causation that can accurately reflect the complexity and diversity of the social world that is a part of the natural system (Rutzou, 2017).

The goal of this study is to explore some of these dynamics in the context of the Tsitsa Project (TP), which took place in the Tsitsa River Catchment. The TP offers an interesting context within which to explore these dynamics, given that researchers have engaged with stakeholders in the catchment, on different scales, under the umbrella of 'participatory research' and, in particular because governance development research is designated in terms of 'participatory governance'. The title further includes a question of epistemic justice as the overall thesis, but this report only speaks to what participation means for the TP stakeholder-participants.

The Tsitsa Project Governance CoP engaging with members the of Tsitsa catchment community in a 'learning words' workshop to learn words in English and isiXhosa to build a vocabulary for further engagements.

Methods

Narrative interviews were conducted with catchment residents, researchers, implementing agents and government (funding). Ten out of the seventeen interviews were conducted via the Zoom platform, due to the restriction of movement during the COVID-19 pandemic.

Poetic analysis was used to represent the findings. Poetry is an arts-based approach, which holds the potential to appeal to a wider range of audiences, especially the subjective experiences of the humans in a complex social-ecological system (Fernandez-Gimenez, 2015; Fernandez-Gimenez et al., 2019). Appealing to a wider audience is also helpful in the transdisciplinary kind of work that the TP engages in, in order for the different stakeholder groups to easily understand each other's subjective experiences of participation, and to understand each other's meaning of true and beneficial participation.

Findings

"Hope" is a poem created from the narrative of a Tsitsa River catchment resident:

Hope

I was always interested in sports,
So, I did a diploma in sports development.
I once went to a multi-racial school,
but they did not have boxing and soccer,
which were my interests.
I changed schools to go back to the township,
So I could improve my talent and be part of the development.

I stayed in Cape Town for years without being employed
I was not going to use my diploma as I had envisioned
The only way you can get a job is having connections
or joining the DA
but I was in the ANC.

I heard that there were opportunities at home,
I decided to go back, looking for greener pastures.

I researched things that could better the youth,
but that needed money.
I put in applications,
No luck, no response.
But that too did not work.
People had hope.
I lost hope because of the lack of support.

We were able to fight to get electricity,
Electricity was installed,
More opportunities came after.
We started fighting amongst ourselves.
After the research,
they would make sure that implementation happens.
We were hopeful it would bring opportunities to the village;
creation of jobs and skills.
When we saw white people, we were hopeful;
We knew that this project will help us as a community
We saw a lot of progress with the vertiver grass,
people being able to provide for their families.

People were educated about field fires.
the Tsitsa Project teaches a lot about nature,
I realised there are things I could do to help with what the TP is doing.
I was always the one delegated to attend these workshops
that is why I wanted to participate in this project.
It has helped me develop my skills
and has shared knowledge that could help develop the community.
People were generous about sharing knowledge.

I was disappointed at how CLOs* were treated;
they are not seen as important as I thought.
I was disappointed with the amount of money;
I expected much more.

Those challenges made me look at it differently;
we were so excited after a long time of not working;
looking forward to being able to feed our families,
but the money was not much.
I stayed because I liked it,
it was handled by capable hands.
I loved my job, but I also like money.

*Community Liaison Officers

The poem shows that much of his participation centred around the theme of hope, especially hope for the betterment of himself, his family, and his community, through opportunities, skills sharing and development. *'People had hope'* and *'when we saw white people, we were hopeful'*. The struggles of this young man in a foreign land is to look for a better life, but he is faced with multiple challenges. He then returns home to try to make it for himself and his community, only to face further obstacles. Still in the spirit of hope for his people, we see him fighting for services and finally succeeding in that one instance, *'We were able to fight to get electricity'*. He acknowledges coming into the Tsitsa Project with the same idea of his participation leading to progress and betterment of himself, his family, and his community being achieved in some respect, but ends up with disappointment pertaining to other aspects. The TP brought the improvements as he had hoped, *'It has helped me develop my skills'* and *'has shared knowledge that could help develop the community'*. The disappointments on the other hand, *'I was not going to use my diploma as I had envisioned'* and *'I was disappointed at how CLOs were treated; they are not seen as important as I thought'*.

In this poem, we see that participation for this participant means to make a difference, and given his context, the struggle of a young black man hailing from a rural community, a very impoverished area isolated from many of the services, such as good schools and job opportunities. He chooses to invest his time and efforts in activities that will make the situation better for his community.

This short extract in the poetic form reveals much about the participant in terms of how he sees himself in his community, what he is good at, and what he prefers, and many other ways that grant us access to his framing of participation. Using the poetic voice has allowed me to reveal so much about the participant without re-interpreting his words too much, and seeing in one take the complexity of some of the interests to be considered, on top of many others in the management of natural resources.

Mapping key drivers of ecological change and analysing equity dimensions of the ecosystem (dis)services flows in the Kat River Valley catchment

Student: EA Seriki
Supervisors: ON Odume and CF Nnadozie
Degree: MSc (Water Resource Science)

Demographic uprise impacts the production and consumption of economic ecosystem services. Global statistics for the past 45 years show that the world population has increased by 3.9 billion to 7.96 billion and is estimated to reach 8.1 bn by December, 2022 (World Bank Group, 2020). In 2022, the population of South Africa increased by 4 million and is estimated to hit 65.86 million by 2027 (Dorling, 2021; House & Street, 2017). Over the past 50 years, fishing, invasive alien species, and freshwater pollution appear to be the most exploited key drivers of ecological change in the aquatic ecosystem. Relatively, the impacts on biodiversity growth, hydrological cycles, and water quality result from climate change drivers, algal bloom, and eutrophication (Singh & Singh, 2017).

Figure 1: Kat River Valley Catchment Management Forum members and IWR team at Mpofu training centre.

The Kat River valley was severely contested by settlers in the early days of development; they came into the area hopeful and hardworking, dreaming of success, only to have political, economic, and governmental changes fail them. The catchment is densely populated and harbours one of the biggest citrus orchards for exportation. There are zealous and optimistic people in the Kat River Catchment yearning for the opportunity and training for advanced development. However, the catchment faces varying socio-ecological and water governance challenges, such as degradation, river pollution, heavy overgrazing, and unfair water allocation (Holtzhausen, 2006). The increased population pressure driving the ecological changes poses broad negative impacts on social, economic, and governance sectors, hence the call for participatory mapping of ecosystem services (ES).

The call is for proper management of the social-ecological systems as an integral component and institutional environmental promotion. Participatory mapping of the catchment with the stakeholders is critical. The value of the aquatic ecosystem for some societal social groupings is based on their different beliefs. (De Wet & Odume, 2019).

A guide to the National Water Act of 1998 pledged one cycle of sustainable, and well-managed water resources. The 'cycle' refers to the overall sustainable management of all the nation's resources: wetlands, dams, groundwater, and rivers. Although the intention of the Act is to recognise and implement multi-dimensional equity in societies, not all the local communities have benefited because of inadequate information dissemination and lack of local community representation in the policy and decision-making sections of water resources management and security. Furthermore, the conceptualization of equity is not thoroughly consolidated as Recognitional and Contextual equity are suppressed while Procedural and Distributive equity are frequently cited. In South Africa, Distributional, Procedural, Recognitional, and Contextual equity should be seen as an interrelated multi-dimensional framework, notably for engaging local communities to access and allocate available resources (McDermott et al., 2013). To gain insight into the Kat River catchment ES and key drivers of ecological change, the integration of the knowledge and value of relevant local and technical stakeholders will be collected to provide a map outcome. Significantly related scientific literature and semi-structured interview questions for the stakeholders, commercial, middle-scale, and emerging farmers will be examined to further analyse the equity dimensions of the ecosystem (dis)service flow.

Objectives

1. To map ecosystem (dis)services flow and the key drivers of ecological change in the Kat River catchment;
1. To analyse the equity dimensions of the ecosystem (dis)services flow in the Kat River catchment.

Figure 2: Kat River Valley Catchment Management Forum members and IWR team on the river site demonstrating Mini SASS.

Understanding how to foster an effective facilitation practice for transformative social learning in catchment management: a case study of two catchments in South Africa

Student: K Siyengo
Supervisors: J Cockburn, T Lanye and MT Weaver
Degree: MSc (Environmental Science)

The South African water resource management sector, though under a democratic era with a transformative mandate highlighted in the National Water Act of 1998, has prevailing governance issues. These can largely be solved under effective collaborative mechanisms adopted by all water users in catchments (Zwarteveen et al., 2017). Social learning as an inherent property of stakeholder engagement and collaboration contributes directly to effective and meaningful water resource management. The Living Catchments Project by the South African National Biodiversity Institute (SANBI), funded by the Department of Science and Innovation (DSI) through the Water Research Commission (WRC) intends to strengthen water governance in South Africa by building and nurturing communities of practice, not only to contribute to the sustainable development agenda of 2030 which calls for a transformative vision towards economic, social and environmental sustainability, but also to accelerate collaboration and to grow capacity for transformative social learning facilitation practice across river catchments in South Africa.

In South Africa, river catchment systems refer to the dynamic capacity of interacting socio-ecological elements of an area bounded by a river basin (Adger et al., 2021). Among many other uses, catchments are particularly important in ensuring a constant supply of water feeding into rivers; they maintain the upkeep of key fauna and flora and play an extremely important role in ensuring that sustainable development goals, such as the provision of water and food, are possible, therefore playing a vital role in social wellbeing (Riddiford, 2021). Under the Living Catchments project, four primary catchments were identified under the Strategic Water Source Area (SWSA) banner: the uMzimvubu, Tugela, Berg and Breede, and Olifants catchments. This study focused on the Upper uMzimvubu and the Olifants catchment.

The aim of this study was to understand the process and the practice of facilitating social learning and stakeholder engagement in the two above-mentioned catchments; specifically, to see where and how learning is happening. Key questions included focusing on what the role of social learning was, what tools and practices are, and how they are used for transformative social learning, as well as discovering the elements of transformative social learning as seen in the catchments through facilitation.

The study addressed these questions through a qualitative case study approach using observation, reflection, and semi-structured interviews as methods of data collection. In addition to this, the Social Learning, Knowledge Management and Mediation (SLKMM) framework of social learning practices was used as a way of understanding the facilitation practice in the two catchments. A number of facilitators, convenors and stakeholders were interviewed during this research period and a number of catchment activities and engagements were observed and reflected upon. These included workshops, field visits, strategy planning engagements, meetings, forums, social learning exchanges and other community of practice platforms which were available in the catchments (Figure 1).

Results

The two catchments show a number of similarities and differences when it comes to transformative social learning facilitation. Convenors of catchment partnerships such as the Kruger 2 Canyon (K2C) in the Olifants and Environmental Rural Solutions (ERS) in uMzimvubu play a vital role in bringing stakeholders together to ensure not only the management of the catchment, but also effective engagement and collaboration. There is value in facilitating not only with governmental organisations but also engaging with key stakeholders such community members, traditional authority, NGOs, researchers, policy makers and implementers on the ground. A key thread across the suggested facilitation was a focus on a bottom-up approach which is contextual to the different groups and adds unique value to each. Field visits, learning exchanges and learning colloquiums were frequently mentioned by stakeholders where learning takes place in the catchment. A key emphasis was also placed on the value of youth involvement to translate this learning, especially to the community, in the form of Environmental Monitors in the Olifants, and Eco Champs in uMzimvubu. The visibility of specifically transformative facilitation saw facilitation practice recommendations, such as including more role-players, looking at the issues of language for different stakeholders, addressing and adapting key communication models, engaging with different tools of engagement, incorporating a greater wealth of indigenous knowledge, being flexible, and having a range of internal practices rather than one specific facilitation practice.

Landscape Ecology

Evaluating trade-offs from intensified practices in communal livestock systems in South Africa using an Integrated Farming Systems Approach (TOCASA)

AR Palmer
April 2019–March 2022

Sponsor: Coventry University
Collaborators: Coventry University, Rothamsted Research (UK), Conservation SA, the Institute for Water Research at Rhodes and Stellenbosch University.

The project aims to better understand the socio-ecological systems (SES) of communal grazing areas, focusing on governance of communal grazing systems as common property regimes, and the links between governance and degradation of communal rangeland. Using a large aperture scintillometer, Prof. Tony Palmer determined the water use of the black and silver wattle trees which have invaded the hill-slope seeps of the Drakensberg foothills. The grasslands associated with these hill-slope seeps have been invaded by silver wattle (*Acacia dealbata*), and black wattle (*Acacia mearnsii*), historically planted for woodlots, has subsequently invaded upland areas and the riparian zone. Both these landscape habitats had been grasslands and very important grazing resources, which have now been replaced by unpalatable wattle trees. The water used by these trees has radically altered catchment run-off, reducing the water available to downstream communities and to grazing areas. The IWR component of the project has determined that approximately nine percent (274 km^2) of this region was invaded by wattle, which represents an annual water use of approximately 253 000 ML.

Exploring rangeland integrity to support ecosystem-based livelihoods in the Eastern Cape

B Gusha and D Gwapedza
April 2022 – March 2024

Sponsor: Water Research Commission
Collaborators: O Gwate (University of Free State)

Rangelands provide various services, including food for millions of people and large landscapes for livestock and wildlife grazing. Despite their importance, rangelands continue to be threatened by changes in land cover, land use, overgrazing, as well as alien invasive vegetation and veld fires. The magnitude of the potential impacts of these threats to rangeland productivity is poorly understood, although land degradation is listed as a major threat to the productivity of these systems and is estimated to cost more than $US40 billion annually (FAO, 2010). In addition to this, considerable debate remains around the extent to which land degradation occurs under the different rangeland management and land tenure systems, and what the main drivers of this degradation are.

Regardless of land degradation, communal rangelands continue to provide different ecosystem services, such as sources of forage for free-grazing animals, as well as a source of woody products, water and wildlife. In South Africa, rangelands comprise the grassland, arid savannah, semi-arid savannah, thicket, Nama Karroo, Succulent Karroo, Desert and Fynbos biomes. These rangelands are multi-purpose, with communal, commercial livestock and wildlife production as the main activities. In contrast, the amount of each ecosystem service currently used in a specific area in each time period is influenced by biophysical elements and the desire for and value of the services to the user.

There have been and continue to be several studies conducted in the Tsitsa River catchment of the Eastern Cape, South Africa, to improve the understanding of the landscape in various forms. In an attempt to improve the rangeland integrity to supply ecosystem services, this study involved developing and completing a regional modelling application in the catchment under WRC project number 2243/1/15. The project implemented a Soil And Water Assessment Tool (SWAT) model to simulate sheet and rill erosion and the resultant sediment yield. A gully erosion model supplemented the SWAT application. The focus of the previous project was to estimate regional sediment yield and associated impacts on the proposed construction of a new dam. Project 2243/1/15 implemented SWAT hydrology at a regional scale to model sediment yield. Another project looked at the opportunities for improving livelihoods through landscape greening in the same catchment (777/1/18), while another project was conducted (KV 328/1/14), covering the larger uMzimvubu catchment to conceptualise a long-term monitoring project to capture the impact of the proposed dam on environmental, socio-economic, and agricultural aspects. Other projects, such as 2433/1/18, worked in the uMzimvubu Water Project to conduct baseline indicators for long-term impact monitoring.

The following are the aims of the project:

1. To determine the productivity and extent of rangeland degradation in the communal rangelands of the Eastern Cape;
2. To apply a spatially distributed hydrological model to estimate the catchment water balance and link this to ecosystem/rangeland productivity and community water supply needs;
3. To conduct a social assessment to determine community perceptions of rangeland changes over time, species changes, and general ecosystem services from the rangeland, and how these could be enhanced to improve their livelihoods;
4. To facilitate rangeland management practices (plans), propose the formation of livestock associations, and reinstatement of traditional rangeland management practices.

Experimental enclosures set up to estimate rangeland productivity.

POSTGRADUATE ACTIVITIES

Gendered perceptions of threats to rangeland ecosystem services in the Tsitsa River catchment

Student: A Khinkwayo
Supervisors: B Gusha and C Shackleton
Degree: BSc (Honours)

A wide range of goods known as ecosystem services (ES) are produced by rangelands, including but not limited to feed for cattle grazing, wild vegetables, and wood. However, degradation undermines the ability of these rangelands to supply the ecosystem services, negatively affecting human wellbeing and livelihoods, particularly with respect to provisioning ES. This study explored gendered perceptions of threats to ecosystem services and provided significant insights for opinions and issues that can be used to provide recommendations on measures that local communities can implement to mitigate and adapt to the threats. Focus group discussion and mapping of ecosystem services, followed by in-depth one-on-one interviews were conducted in two traditional villages, Lower Tsitsana and Basotho East areas in Maclear.

Findings show that while some ecosystem services are used differently by males and females, others are used similarly. There was a significant variation in the usage of wild vegetables (77% females, 46% males) and honey (12% females, 54% males). Both genders had a high percentage of people using firewood (100% females, 92% males), fencing wood (96% females, 82% males) and fresh water (81% females, 73% males). Fire and drought were cited as the two main threats by both genders, with women reporting that fire affects grass for brooms (54%) and drought affects wild vegetables (69%), while men reported that water supply is affected by drought (69%) and that fire impacts grass for animal grazing (73%). These results imply that gender plays an important role in understanding how different genders benefit from ES, and this finding should be considered in ES frameworks.

People's perceptions of supply and demand for rangeland provisioning ecosystem services in the Titsa River catchment

Student: D Phooko
Supervisors: B Gusha and C Shackleton
Degree: BSc (Honours)

Despite the beneficial services which rangelands provide to sustain people's livelihoods, they are reported as degraded by overgrazing and over-harvesting of the services, and thus the supply of the services is negatively affected. Using both focus group discussions and one-on-one interviews with heads of households, this study aimed to assess people's perceptions of supply and demand of provisioning ecosystem services in a communal rangeland of the Tsitsa River catchment in the Eastern Cape. The findings show the most important services derived by livestock and non-livestock owners are fodder (67%) and firewood (33%), respectively. However, the supply of these services has decreased because of overgrazing, fire, and over-harvesting. Conversely, the demand has increased because of the rangeland's inability to provide these services. In order to manage the rangeland sustainably, it will be imperative to raise awareness to educate people about the importance of deriving these services responsibly and to give them an opportunity to develop measures to implement to ensure the rangeland's constant and sufficient supply of the services.

Research Outputs

PEER REVIEW JOURNALS AND CONFERENCE PROCEEDINGS

Akamagwuna FC, Odume ON and Richoux NB (2022) Exploring the community structure of Afrotropical macroinvertebrate traits and ecological preferences along an agricultural pollution gradient in the Kat River, Eastern Cape, South Africa. *Ecological Indicators*. https://doi.org/10.1016/j.ecolind.2022.108570.

Akamagwuna FC, Choruma DJ, Ntloko P, Nnandozie CF and Odume ON (2022) Functional groups of Afrotropical EPT (Ephemeroptera, Plecoptera and Trichoptera) as bioindicators of semi-urban pollution in the Tsitsa River Catchment, Eastern Cape, South Africa. *PeerJ.* doi: 10.7717/peerj.13970

Biggs R, Clements HS, Cumming GS, Cundill G, de Vos A, Hamann M, Luvuno L, Roux DJ, Selomane O, Blanchard R, Cockburn J and Palmer CG, et al. (2022) Social-ecological change: insights from the Southern African Program on Ecosystem Change and Society. *Ecosystems and People.* https://doi.org/10.1080/26395916.2022.2097478

Chibwe M, Odume ON and Nnadozie CF (2022) A review of antibiotic resistance among *Campylobacter* species in human, animal and water sources in South Africa: a One Health Approach. *Journal of Water and Health*. doi: 10.2166/wh.2022.146

Choruma DJ, Akamagwuna FC and Odume ON (2022) Simulating the Impacts of Climate Change on Maize Yields Using EPIC: A Case Study in the Eastern Cape Province of South Africa. *Agriculture*. 10.3390/agriculture12060794.

Dessie BK, Tessema B, Asegide E, Tibebe D, Alamirew T, Walsh CL and Zeleke G (2022) Physicochemical characterization and heavy metals analysis from industrial discharges in Upper Awash River Basin, Ethiopia. *Toxicology Report*. https://doi.org/10.1016/j.toxrep.2022.06.002

Edegbene AO, Akamagwuna FC, Arimoro FO, Akumabor EC and Kaine EA (2022) Effects of urban-agricultural land-use on Afrotropical macroinvertebrate functional feeding groups in selected rivers in the Niger Delta Region, Nigeria. *Hydrobiologia*, 849, 4857-4869.

Edegbene AO, Odume ON, Akamagwuna FC, Ntloko P, Arimoro FO, Edegbene TT, Akumabor E, Efe Ogidiaka E, Kaine EAK and Nwaka KH (2022) A macroinvertebrate-based multimetric index for assessing ecological condition of forested stream sites draining Nigerian urbanizing landscapes. Sustainability.

Edegbene AO, Abdullahi Y, Osimen EC, Ogidiaka E, Omovoh BO and Akamagwuna FC. (2022) Are zooplankton useful indicators of ecological quality in Afrotropical ephemeral stream impacted by human activities? *Environmental Monitoring and Assessment.* https://10.1007/s10661-022-10061-4.

Edegbene AO and Akamagwuna FC (2022) Effects of urban-agricultural land-use on Afrotropical macroinvertebrate functional feeding groups in selected rivers in the Niger Delta Region, Nigeria. *Hydrobilogia.* https://doi.org/10.1007/s10750-022-05034-0

Edegbene AO and Akanagwuna FC (2022) Insights from the Niger Delta Region, Nigeria on the impacts of urban pollution on the functional organisation of Afrotropical macroinvertebrates. *Scientific reports*. https://doi.org/10.1038/s41598-022-26659-0

Garba F, Ogidiaka E, Akamagwuna FC, Nwaka KH and Edegbene AO (2022) Deteriorating water quality state on the structural assemblage of aquatic insects in a North-Western Nigerian River. *Water Science*. https://doi.org/10.1080/23570008.2022.2034396.

Feio MJ, Hughes RM, Serra SRO, Nichols SJ, Kefford BJ, Lintermans M, Robinson W, Odume ON et al (2022) Fish and macroinvertebrate assemblages reveal extensive degradation of the world's rivers. *Global Change Biology*. DOI: 10.1111/gcb.16439

Fikadu T, Teferi E, Dubale B, Gusha B, Mantel SK, Tanner JL, Palmer CG, Woldu Z, Alamirew T and Zeleke G (2022) Implications of Watershed Management Practices on Water Availability Using Hydrus-1D Model in the Aba Gerima Watershed, Upper Blue Nile Basin, Ethiopia. *Water*, *14*(19), p.3095.

Arias ME, Farinosi F and Hughes DA (2022) Future Hydropower operations in the Zambezi River basin: Climate impacts and adaptation capacity. *River Research and Applications*. DOI: 10.1002/rra.3958

Januchowski-Hartley SR, Pawar SK, Yang X, Jorissen M, Bristol R, Mantel S, White JC, Januchowski-Hartly FA, Roces-Diaz JV, Gomez CC and Pregnolato M (2022) Supporting proactive planning for climate change adaptation and conservation using an attributed road-river structure dataset. *Journal of Environmental Management*, 321, 115959. https://doi.org/10.1016/j.jenvman.2022.115959.

Keke UN, Arimoro FO, Edegebene AO, Akamagwuna FC, Assie FAGJ and Odume ON (2022). Biotic homogenization of stream macroinvertebrates in an Afrotropical Anthropocene: Land use and ecological correlates. *Frontiers in Environmental Science.* DOI:10.3389/fenvs.2022.1022776

Keke UN, Arimoro FO, Ayanwale AV, Odume ON and Edegbene AO (2022) Weak relationships among macroinvertebrates beta diversity (Β), river status and environmental correlates in a tropical biodiversity hotspot. *Ecological Indicators*. https://doi.org/10.1016/j.ecolind.2021.107868

Libala N, Odume ON and Palmer CG (2022) Engaging with communities to develop an understanding of livestock grazing practices in relation to hill slope seep wetlands in the Tsitsa River catchment, Eastern Cape. *Anthropocene 19* https://doi.org/10.1016/j.ancene.2022.100342
Libala N, Griffin NJ, Nyingwa A and Dini J (2022) Freshwater ecosystems and interactions with the SDG 2030 Agenda: implications for SDG implementation in South Africa. *African Journal of Aquatic Science*, 47:3, 353-368, DOI: 10.2989/16085914.2022.2109574
Lidzhegu Z, Ellery WN and Mantel SK (2022) The geomorphic origin of large wetlands in Africa's elevated drylands: a Geographic Information System and Earth Observation approach. *South African Geographical Journal*, 2022, 1-23. https://doi.org/10.1080/03736245.2022.2030247
Lodder Q and Slinger JH (2022) The 'Research for Policy' cycle in Dutch coastal flood risk management: the Coastal Genesis 2 research programme. *Ocean and Coastal Management*, 219 [106066] https://doi.org/10.1016/j.ocecoaman.2022.106066
Maasri A, Jähnig SC, Adamescu MC, Adrian R, Baigun C, Baird DJ, Batista-Morales A, Bonada N, Brown LE and Odume, ON et al (2022). A global agenda for advancing freshwater biodiversity research. *Ecology Letters*. DOI: 10.1111/ele.13931
Odume ON (2022) The contribution and value of the trait-based approach to water resource protection. *African Journal of Aquatic Science*. DOI:10.2989/16085914.2022.2047590
Odume ON, Onyima BN, Nnadozie CF, Omovoh GO, Mmachaka T, Omovoh BO, Uku JE, Akamagwuna FC and Arimoro FO (2022). Governance and Institutional Drivers of Ecological Degradation in Urban River Ecosystems: Insights from Case Studies in Africa Cities. *Sustainability*. DOI.org/10.3390/su142114147
Ogidiaka E, Ikomi RB, Edegbene AO and Akamagwuna FC (2022) Exploratory accounts of the increasing pollution gradients and Macroinvertebrates structural assemblage in an Afrotropical estuary. *Biologia*, 77, 2103-2114.
Omovoh BO, Arimoro FO, Anyanwaleb AV, Egwim EV, Omovoh GO, Akamagwuna FC, Zakari H, Edegbene AO (2022) Macroinvertebrates of Wupa River, Abuja, Nigeria: Do environmental variables pattern their assemblages? *Biology Insights*. http://www.mediterraneanjournals.com/index.php/bi/article/view/612
Owusu A, Mul M, van der Zaag P and Slinger JH (2022) May the odds be in your favour: Why many attempts to re-operate dams for the environment stall. *ASCE Journal of Water Resources Planning and Management*, 148(5), [04022009] http://doi.org/10.1061/(ASCE)WR.1943-5452.0001521
Palmer CG, Fry A, Libala N, Ralekhetla M, Mtati N, Weaver MJT, Mtintsilana Z and Scherman P-A (2022). Engaging society and building participatory governance in a rural landscape restoration context. *Anthropocene*, 100320. doi.org/10.1016/J.ANCENE.2022.100320
Palmer CG and King J (2022) Perspectives on Protecting African Freshwater Ecosystems in the Anthropocene. *African Journal of Aquatic Science*. DOI:10.2989/16085914.2022.2132045
Ssewankambo G, Kabenge I, Nakawuka P, Wanyam J, Zziwa A, Bamutaze Y, Gwapedza D, Palmer CT, Tanner J, Mantel S and Tessema B (2022). Assessing soil erosion risk in a peri-urban catchment of the Lake Victoria basin. *Modeling Earth Systems and Environment*, https://doi.org/10.1007/s40808-022-01565-6
Tanner JL, Mantel SK, Paxton B, Slaughter AR and Hughes DA (2022) Impacts of climate change on rivers and biodiversity in a water-scarce semi-arid region of the Western Cape, South Africa. *Frontiers in Water*, 4, 949901. doi.org/10.3389/frwa.2022.949901
Tessema B, Wilson B, Daniel B, Kristiansen P and Baldock JA (2022) Functional Links between Biomass Production and Decomposition of Vetiver (Chrysopogon zizanioides) Grass in Three Australian Soils. *Plants*. https://doi.org/10.3390/plants11060778
Vreugdenhil HSI, Janssen S, Hermans LM, Slinger JH (2022) Cooperating for added value: Using participatory game theory in implementing nature-based flood defences. *Ecological Engineering*, 176, [106507]. https://doi.org/10.1016/j.ecoleng.2021.106507
Weaver MJT, Ralekhetla M, Mtati N, Gusha B and Mti N (2021) Assessing the implications of COVID-19 for the facilitation of social transformative learning in rural communally-owned landscape contexts. In Kulundu-Bolus, I, Chakona, G and Lotz-Sisitka, H (Eds). *Stories of collective learning and care during a pandemic: Reflective research by practitioners, researchers and community-based organisers on the collective shifts and praxis needed to regenerate transformative futures.* Grahamstown: Transforming Education for Sustainable Futures (TESF) and the Environmental Learning Research Centre (ELRC). https://doi.org/10.5281/zenodo.5704833
Xoxo S, Mantel SK, De Vos A, Mahlaba B, Le Maître D and Tanner JL (2022) Towards SDG 15.3: The biome context as the appropriate degradation monitoring dimension. *Environmental Science & Policy*, *136*, pp.400-412.
Yunusa IAM, Palmer AR, Kamululdeen J and Punthakey JF (2022) Contrasting responses to soil and water salinity in stomata and canopy traits

produced convergence of water-use in tomatoes (Solanum esculentum) and okra (Abelmoschus). *Journal of the Science of Food and Agriculture* 102 (8), 3227-3236.

Zaccheus S, Nyakairu GWA, Tebandeke E and Odume ON (2022) Overview of African water resources contamination by contaminants of emerging concern. Science of the Total Environment. http://dx.doi.org/10.1016/j.scitotenv.2022.158303

IN PRESS AND SUBMITTED ARTICLES

Akamagwuna FC, Odume ON and Richoux NB (2022) Agricultural land-use influences functional feeding groups of Afrotropical Ephemeroptera, Plecoptera and Trichoptera in the Kat River, Eastern Cape, South Africa. *African Journal of Aquatic Science.*

Edegbene AO and Akamagwuna FC (in press) Effects of urban-agricultural land-use on Afrotropical macroinvertebrate functional feeding groups in selected rivers in the Niger Delta Region, Nigeria", *accepted. Hydrobilogia.*

Libala N, Clifford-Holmes JC, Bester R, Ralekhetla M, Mti N, Fry A, Weaver MJT and Palmer CG (in prep) A systemic view of the Governance Capabilities Pathway.

Nsengimana V, Nzibaza V, Nzarora A, Magume P, Kaplin B, Tanner J, Mantel S, Libala N, Weaver M, Palmer CG (in prep) Using an Adaptive Planning Process to Plan for Water Resources Management in Rwanda.

Odume ON, Akamagwuna FC, Ntloko P, Dallas HF, Nnadozie CF, Barber-James HM (2022) A trait database for Southern Africa freshwater invertebrates. *African Journal of Aquatic Science-Accepted with minor correction.*

Okal HA, Hughes DA and Tanner JL (2022) Investing in Sub-Saharan Africa Water Resources; Technology vs People. A WCC-OFW Publication on "Climate Resilient Water Resources Management – Driving the Conversation Forward" (accepted)

Weaver MJT, Cockburn J, Mtati N and Palmer CG (under review) Transformative processes in a WEF nexus landscape: a case study of two vignettes from the Tsitsa Project.

Weaver MJT, Henriksson R, Nxumalo N, Porroche-Escudero A and Palmer CG (in prep) Exploring the impact of learning catalysed from participation in the Resilient Benefits Project: A value creation approach.

Weaver MJT, Wolff MG, Libala N, Tessema B and Palmer CG (in prep) Building participation capabilities in an African context: lessons learned from the implementation of the Adaptive Systemic Approach.

Weaver MJT, Rosenburg E, Cockburn J, Madiba M, Mvulane W and Sithole P (in prep) How did an online course in natural resource management create value for its stakeholders in South Africa? Applying a social learning evaluation framework to novel contexts.

Weaver MJT (book chapter, completed, awaiting publisher) Breaching the gap: Translating commissive talk to action in multi-level water governance arrangements.

BOOKS

Chapter in book

Odume ON and De Wet C (2022) Chapter 22. Environmental Ethics and Sustainable Freshwater Resource Management In: TM Letched Ed) Water and Climate Change: Sustainable Development, Environmental and Policy Issues. ISBN: 978-0-323-99875-8.

Odume ON (2022) Chapter 14. Sustainable freshwater management—the South African approach In: TM Letcher (Ed) Water and Climate Change: Sustainable Development, Environmental and Policy Issues. ISBN: 978-0-323-99875-8.

Reports

Griffin N, Odume N and Slaughter A (2022) Developing long and short terms technical solutions, mitigation measures and decision support strategies that will improve water quality in the Grootdraai Dam Catchment. Deliverable 2: Communication strategy. Report to Water Research Commission.

Griffin NJ, Mensah PK, Odume ON, van Niekerk HJ and Ncube L (2022) Revision of the 1996 South African water quality guidelines: Development of risk-based approach using aquatic ecosystems responses. Deliverable 4: Design philosophy for pilot testing of revised guideline. Report to Water Research Commission.

Gokool S and Palmer AR (2022). Initial *Cannabis sativa* distribution maps. Third Deliverable for WRC Project C2021/2022-00442. Water Research Commission, Pretoria, South Africa.

Mantel SK, Gokool S, Palmer AR, Zenani K and Denton G (2022). Progress on *Cannabis sativa* growth environment report. Fourth Deliverable for WRC Project C2021/2022-00442. Water Research Commission, Pretoria, South Africa.

Mgaba N, Griffin N, Mensah PK, Tumwesigye E, Owowenu E, Mtintsilana Z, Nnadozie C and Odume ON (2022) Microplastics as emerging contaminants: method development, ecotoxicity testing and biomonitoring in South African water resources. Final report. Report to Water Research Commission.

Odume ON, Mensah PK, Griffin NJ, van Niekerk HJ and Ncube L (2022) Revision of the 1996 South African water quality guidelines: Development of risk-based approach using aquatic ecosystems responses. Deliverable 3 (Incorporating feedbacks/comments from Deliverable 2): Technical report on guideline revision – the reasoning behind the revised guidelines in light of the findings from the literature and data availability. Report to Water Research Commission.

Odume ON, Okeja U, Mdludla O and Tavengwa N (2022) Contribution of an ethically grounded and value-based approach to water governance-The case of two contrasting catchments. Report for Water Research Commission, Report No. 2934/1/22

Palmer A, Smart K, Gokool S and Zenani KTS (2022) *Cannabis sativa* research: Scoping review. Water Research Commission Project C2021/2022-00442.

CONFERENCE PRESENTATIONS AND NON PEER REVIEWED PUBLICATIONS

Akamagwuna FC, Odume ON and Richoux NB (2022) Agricultural advancement influences basal resources supporting an afrotropical river system: insight from the Kat River, Eastern Cape Province, South Africa. The Joint Aquatic Science Meeting, Grand Rapids, Michigan: May 15 2022, 11am EST.

Ali AA, Odume ON, Nnadozie CF and Akamagwuna FC (2022) The influence of hydraulic biotopes on the taxonomic assemblage structure of macroinvertebrates on macroplastics in selected headwater streams. The 59th Southern African Society of Aquatic Scientists Congress, University of Free State, Bloemfontein, 26-30 June 2022.

Bristol R, Januchowski-Hartley SR, Pawar SK, Yang X, Kherlen S, Jorissen M, Mantel SK, Pregnolato M and White J (2022) Creating a spatially explicit road-river infrastructure dataset to benefit people and nature. EGU General Assembly 2022, Vienna, Austria, 23 – 27 May 2022, EGU22-12901. https://doi.org/10.5194/egusphere-egu22-12901.

Gwapedza D, Mantel SK, Bonte B, Theron S, Mabohlo S, Xoxo S, Paxton B, Barreteau O and Tanner JL (2022) A stakeholder-driven process to develop a sustainable water resources management plan in the Koue Bokkeveld farming region, Western Cape-South Africa, [Oral Presentation (No. IAHS2022-488)]. Paper presented at the IAHS-AISH Scientific Assembly 2022, Montpellier, France. 29 May – 3 June 2022

Ntshangase A. 2022. Understanding ecological infrastructure in relation to people in the Tsitsa River catchment, Eastern Cape, South Africa. Presented at the Land Rehabilitation Society of Southern Africa (LaRSSA) 9th Annual conference, in Parys South Africa, 12–15 September 2022.

Okal HA, Tanner JL, Mantel SK and Hughes DA (2022) Comparison and Validation of Outputs from Global Hydrological Models against Local Hydrological Data in Sub-Saharan Africa. IAHS 2022 Scientific Assembly in Montpellier, France, 29th May to 3rd June 2022.

Okal HA, Tanner JL, Mantel SK and Hughes DA (2022) Comparison and Validation of Outputs from Global Hydrological Models against Local Hydrological Data in Southern Sub-Saharan Africa. SAHS 2022 Scientific Assembly in Montpellier, South Africa, 10th - 12th October 2022.

Ralekhetla M, Paphitis SA, Kelland L, Mckeown J and Palmer CG (2022) Using poetic voice to explore the nature and meaning of participation, in relation to epistemic justice, in a landscape restoration project, South Africa. Presented at the International Symposium for Poetic Inquiry, Cape town, South Africa, 24th May-27th May 2022.

Ralekhetla M, Paphitis SA, Kelland L, Mckeown J and Palmer CG (2022) Using poetic voice to explore the nature and meaning of participation, in relation to epistemic justice, in a landscape restoration project, South Africa. Presented at the Rhodes University Postgraduate Conference, Makhanda, South Africa, 1st September - 2nd September 2022.

Wasswa P and Tanner JL (2022) A conceptual-perceptual model to assess groundwater recharge dynamics in the upstream of Uitenhage Artesian Basin, South Africa. Paper presented at the South Africa Hydrological Society Conference (SAHS), 26 Degree South Hotel, Muldersdrift-South Africa, 10 Oct – 12 Oct 2022.

Wasswa P and Tanner JL (2022) An assessment of GRACE-Based water storage deficit approach for hydrological drought characterization in Uganda. Paper presented at the 2nd IGAD Water Dialogue Forum, Entebbe-Uganda, 25 Jan – 27 Jan 2022.

Weaver MJT. Impact in Social-ecological Research

Projects: The Hidden Value Catalysed by Transdisciplinary Research Interventions. Center of Excellence in Biodiversity and Natural Resource Management (CoEB), College of Science and Technology, CoEB SEMINAR SERIES, University of Rwanda. 24th of August 2022.

Weaver MJT. Snapshot of the RESBEN Project, an African water-related TD intervention. TD by design, TD-ish by nature. PECS Working Group Seminar Series. 7 September 2022.

Xoxo S, Tanner JL, Hughes DA and Mantel SK (2022) Integrating equity into a water allocation model to promote water sharing in environments with vulnerable stakeholders [Oral Presentation (No. IAHS2022-207)}. Paper presented at the IAHS-AISH Scientific Assembly 2022, Montpellier, France, 29 May – 3 June 2022.

Xoxo S, Tanner JL, Mantel SK and Hughes DA, (2022) On the interface between society and water: Using multi-criteria analysis to explore impacts of periodic water supply. Paper presented at the Center for Postgraduate Studies Conference 2022, Rhodes University, Makhanda, South Africa, 1 – 2 September 2022.

Xoxo S, Tanner JL, Mantel SK and Hughes DA (2022). Evaluating the socio-economic impact of water restrictions in different sub-sectors of an agricultural catchment [Poster presentation]. *SAHS* 2022 Conference, Muldersdrift, South Africa.

Xoxo S, Mantel SK, Tanner JL, De Vos A, Le Maître D (2022) Ecological infrastructure as a sustainable solution for water security of rural communities [Oral Presentation]. South African Hydrological Society (SAHS), Pretoria, 10 – 12 October 2022.

Zenani KTS, Palmer A and Smart K (2022) Water Use of *Cannabis sativa* in the Eastern Cape. Poster presented at the Thicket Forum, Addo Elephant National Park, Addo, South Africa, 11-13 June 2022. www.thicketforum.org.za

Institute for Water Research
Rhodes University
PO Box 94
Grahamstown/Makhanda
6140, South Africa

+27 (0)46 603 8334

iwr@ru.ac.za
http://www.ru.ac.za/iwr/