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IWR

IWR: ARUA Water Centre of Excellence Hub

ARUA African Research Universities Alliance

ARUA Water CoE

Centre for Environmental Water Quality

Institute for Water Research

ANNUAL REPORT 2023

CONTENTS

Abbreviations and Acronyms

ABM	Agent-Based Model
ACDI	African Climate and Development Initiative
ARBs	Antibiotic-resistant bacteria
ARC	Agricultural Research Council
ARGs	Antibiotic-resistant Genes
ARUA	African Research Universities Alliance
ASA	Adaptive Systemic Approach
AWARMN	African Water Resource Mobility Network
BCMM	Buffalo City Metropolitan Municipality
BPG	Best Practice Guidelines
CEC	Contaminants of Emerging Concern
CMF	Catchment Management Forum
CoE	Centre of Excellence
CoI	Co-Investigator
CoRE	Clusters of Research Excellence
CSES	Complex social-ecological system
CWRR	Centre for Water Resources Research
DRDLR	Department of Rural Development, Agriculture and Land Reform
DSS	Decision Support System
DWS	Department of Water and Sanitation
EACEA	European Education and Culture Executive Agency
ECR	Early Career Researcher
EDCs	Endocrine Disrupting Compounds
EDCTP	European and Developing Countries Clinical Trials Partnership
EFTEON	Expanded Freshwater and Terrestrial Environmental Observation Network
ELRC	Environmental Learning Research Centre
ET	Evapotranspiration
EWR	Ecological Water Requirements
EWR	Environmental Water Requirements
FAO	Food and Agriculture Organisation
FRC	Freshwater Research Centre
GHMs	Global Hydrological Models
GIZ	Deutsche Gesellsschaft fur Internationale Zusammerarbeit
GW	Groundwater
HS	Hydrological Signatures
IAHS	International Association of Hydrological Sciences
ICDSST	International Conference on Decision Support System Technology
ICIREWARD	International Centre for Interdisciplinary Research on Water Systems Dynamics
INRAE	Institute for Agriculture, Food and the Environment
ISER	Institute of Social and Economic Research
IWR-RU	Institute for Water Research-Rhodes University
JVs	Joint Ventures
KBV	Koue Bokkeveld
LAS	Large Aperture Scintillometer
LSRWUA	Lower Sundays River Water User Association
MPs	Microplastics
MRC	Medical Research Council
NbS	Nature-based Solutions
NMB	Nelson Mandela Bay
NRF	National Research Foundation
NSE	Nash-Sutcliffe Efficiency
NWA	National Water Act
PCR	Polymerase Chain Reaction
PES	Presidential Employment Stimulus

PGIS	Participatory Geographic Information System
POPs	Persistent Organic Pollutants
Pywr-WQ	Python water resources – Water Quality
RCP	Representative Concentration Pathway
RESBEN	Resilient Benefits
RQOs	Resource Quality Objectives
RS	Remote Sensing
RU-HREC	Rhodes University Human Research Ethics Committee
SADC	Southern African Development Community
SAHS	South African Hydrological Society
SAIAB	South African Institute of Aquatic Biodiversity
SAM	Strategic Adaptive Management
SRVC	Sundays River Valley Collaborative
SSA	Sub-Saharan Africa
SW	Surface water
SWAT	Soil Water Assessment Tool
TD	Transdisciplinary
TMG	Table Mountain Group
TsRC	Tsitsa River Catchment
UAB	Uitenhage Artesian Basin
UKRI	United Kingdom Research and Innovation
UKZN	University of KwaZulu-Natal
WAR	Water allocation reform
WHO	World Health Organization
WRC	Water Research Commission
WRMP	Water Resources Management Plan

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Institute for Water Research Director's report

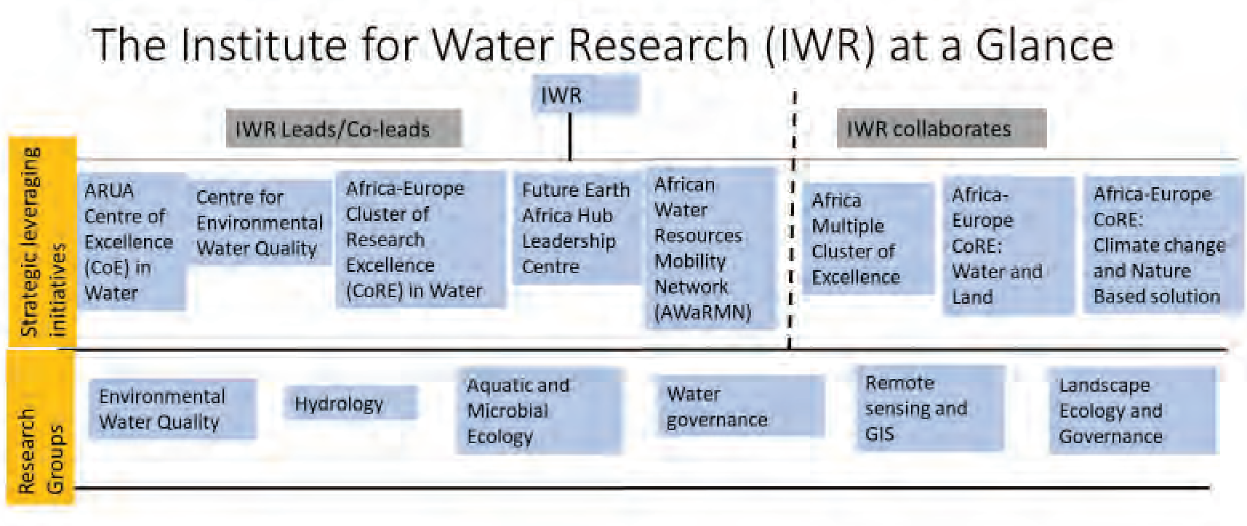
In 2023 we received the exciting news of the promotion of three academic staff within the IWR: Prof. Sukmani Mantel was promoted as Associate Professor, Dr Chika Nnadozie was promoted as a Senior Researcher, and Prof. Odume was promoted as Professor. My warmest congratulations to these colleagues for the milestones achieved, a demonstration of commitment to excellence. Prof. Elizabeth Mack of Michigan State University was appointed visiting Professor to the IWR, bringing the total number of visiting professors to two; the other being Prof. Jill Slinger who continues to play a leading role within the IWR. I am deeply appreciative of the contributions our Visiting Professors make to the IWR.

We continue to position ourselves within the water and related sectors as a leading research institute, and some of the most exciting news for 2023 was the successful application to the National Research Foundation to jointly host the Future Earth Africa Hub Leadership Centre at Rhodes University with the University of Pretoria. The Leadership Centre is a collaborative initiative between the Environmental Learning Research Centre (ELRC), Institute of Social and Economic Research (ISER), the IWR at Rhodes University, and the Future Africa campus at the University of Pretoria. Future Earth is a global network of over 2000 scientists, practitioners and policy makers in the field of sustainability science. Currently funded by the NRF, the Leadership Centre aims to strengthen, grow, and deepen sustainability science on the African continent. We are pleased to be part of this exciting initiative.

ARUA and the Guild of Research-Intensive Universities in Europe has partnered to established Clusters of Research Excellence (CoRE). Rhodes University, through the IWR, in partnership with the University of Ljubljana in Slovenia submitted a successful application, and were awarded the CoRE on water resource management for a sustainable and just future. This is an exciting collaborative initiative that will further strengthen the work of the IWR. The IWR is also collaborating in two other CoREs, one focusing on Water and Land, and the other on Climate Change and Nature-based Solutions. Over the past five years, the IWR has collaborated in the Africa Multiple Cluster of Excellence, which focuses on re-configuring African Studies. Overall, the Institute currently leads or co-leads five strategic leveraging strategic partnerships. There are currently six research groups within the IWR each led by a group leader, working collaboratively on different projects.

Funding and Projects

One of the most exciting events was the award of the Erasmus Plus Project on Nature-based Solutions led by Prof. Sukhmani Mantel. The project aims to strengthen institutional capacity in the field of nature-based solutions through curriculum development. We are very excited to be leading



this large research project, funded by the European Union. The IWR has a total of 18 externally funded projects (12 local, and five international projects) covering topics from water quality, hydrological modelling, climate change, zoonoses and human health risk, equity and water security, etc. Details of their activities appear in the various research projects in this report.

In addition to the Water Research Commission (WRC) and the National Research Foundation (NRF), the Medical Research Council (MRC) is becoming an important funding agency for the IWR. Dr Chika Nnadozie's work on One Health is particularly attractive to the MRC. Our primary international funding sources remain the UK Research and Innovation (UKRI), European Education and Culture Executive Agency (EACEA), European and Developing Countries Clinical Trials Partnership (EDCTP), Swedish Research Council, University of Bayreuth, GIZ, and the Belmont Forum.

In 2023, several research projects come to an end. These include projects on Sustainable Development Goals (SDGs) pathfinding funded by the Belmont Forum, and the large collaborative RESBEN project funded by the UKRI. By December 2024, our flagship project, funded by the Intra-Africa Academic Mobility Scheme, which has supported the majority of students in the Institute, will be coming to an end. We have submitted a Doctoral School proposal to ARUA, which if successful, will continue to support our students financially. The IWR will continue to position itself as the partner of choice for large, collaborative international projects.

Outputs and impact

The IWR remains a research-intensive environment, and in the coming years we will pursue a strategy to accelerate research productivity both in terms of student supervision and publications. In 2023, a total of 18 students were registered in the IWR, pursuing degrees in Hydrology or in Water Resource Science. A total of six students completed and obtained their degrees in 2023: Mr Anthony Fry (PhD, Water Resource Science), Mr Andrew Ali (MSc, Water Resource Science with **distinction**), Ms Zintle Mtinsilana (MSc, Water Resource Science), Ms Nandipha Ngoni (MSc, Water Resource Science), Ms Phatsimo Ramatsabana (MSc, Hydrology) and Ms Noleen Tavengwa (MSc, Water Resource Science with **distinction**). I congratulate these students and their supervisors for the milestones achieved.

Publications remain a priority in the IWR. In 2023, a total of 28 papers were published in peer-reviewed journals. International conference attendance and presentations stand at 19. Projects implemented within the IWR have significant policy and practice dimensions, and readers are invited to engage with the various project reports for their impacts.

The IWR intends to be impactful in the area of citizen science and community engagement. Under the leadership of Ms Khaya Mgaba, the IWR continues to engage with High School students within Makhanda on the importance of water resources and river health. Grade 7 learners from Fikizolo in Makhanda were taught basic principles of river health monitoring using aquatic organisms.

Human capability and wellness

The Institute welcomed two new postdoc fellows and three new students in 2023. The two new postdoc fellows are Dr Fenji Materechera-Mitochi and Dr Djim Diongue. Fenji leads a project on small-scale farming systems and equity imperatives, while Djim is working on groundwater hydrology. The new students, Mr Simphiwe Ngilana (PhD, Water Resource Science), Ms Anelile Gibixego (MSc, Water Resource Science) and Voice Mlonzi (MSc, Water Resource Science) are working on diverse projects, including equity in the land-water-agricultural nexus, macroplastic pollution in rivers, and equity dimensions of water-security challenges. The IWR was pleased to host three presidential employment stimulus (PES) interns for six months: Ms Namhla Mqogi, Ms Sinalo Knzela and Ms Siphamandla Mjuleni, who went through a rigorous six-month training within the IWR which exposed them to different workstreams: laboratory techniques, culture maintenance, ecological field work, stakeholder engagement, project administration and management. I thank Ms Mgaba who leads our community engagement work.

The IWR said goodbye to a number of postdoctoral fellows" Dr Frank Akamagwuna has taken up a fellowship at the University of Alabama, Dr Gusha Buko took up a Senior Lecturer position at the University of Limpopo, and Dr Nolusindiaso Ndara has taken up a fellowship with EFTEON.

Partnerships

The IWR fosters partnerships based on strong, transparent and rich relationships with diverse local, national and international institutions and partners. Our flagship partnerships include the ARUA Water CoE, comprising nine universities on the African continent; the African Water Resources Mobility Network, comprising five African universities and one European University; the Africa-Europe Cluster of Research Excellence in Water Resource Management comprising 10 partner universities in Africa and Europe; Future Earth Africa Hub Leadership Centre with a growing continental network; Africa Multiple Cluster of Excellence, comprising the University of Lagos, Bayreuth University, Joseph Ki-Zebo University, and Moi University. Through these strategic partnerships, IWR continues to expand its footprint continentally and globally.

In 2023, the IWR was invited by the UNESCO Centre at the University of Montpellier to partner with it and 12 other universities to set up an international, interdisciplinary and intercultural collaborative PhD Platform. The other universities are the Australian National University (AU), Dublin City University (IE), Dundee University (UK), IHE Delft (Netherlands), University Cheikh Anta Diop of Dakar (Senegal), Félix Houphouët-Boigny (Côte d'Ivoire), University Mohamed 6 Polytechnique (Morocco), Université Laval (Canada), Université de Sherbrooke (Canada), University Of Barcelona (Spain), and University of California (Irvine). The platform is intended to enrich the PhD experiences of students through exchanges, mobility and joint collaborative training. The first student cohort is expected to commence their Autumn School in 2024.

Locally, the IWR fosters strong collaboration with the Durban University of Technology in the field of microbial water quality research. At Rhodes University, the IWR works closely with colleagues from the Departments of Chemistry, Zoology and Entomology, 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), and Microbiology and Biotechnology. The IWR continues to support the Department of Geography in offering the Environmental Water Management Honours programme.

I especially thank Prof. Rui Krause who has shown interest in and continues to support the analytical chemistry work within the IWR.

Technical capacity

The IWR recognises the importance of strengthening technical capacity and mentorship. In this regard, we are revamping the stream laboratory, which will become our central water quality lab and house all the water quality analytical instruments.

We are in an on-going discussion with the Makana Local Municipality regarding water quality analysis. Some years back, the Municipality established a water quality lab, but this is currently not being used. We aim to assist the Municipality in terms of technical capacity for the lab and are exploring the possibility of an MOU between the Municipality and IWR through the University to have the equipment in the Makana water quality lab relocated to the IWR central water quality lab. If successful, the Municipality would then have access to the central water quality lab for their routine analysis. I thank both Dr Chika Nnadozie and Ms Khaya Mgaba who have been working on revamping the lab, and in the on-going discussion with the Municipality.

The IWR supported Ms Mary Chibwe, Havillah Nnadozie and Sofia Lazar in attending training on portable molecular diagnostics for on-site microbial water quality monitoring. The Water Quality Monitoring training workshop was organised by Newcastle University, through its Water Security Hub. The workshop was hosted at the Kaliti Wastewater Treatment Plant in Addis Ababa, Ethiopia. The workshop provided hands-on training in the analysis of water microbiomes using next-generation sequencing and qPCR assays, equipping participants with basic skills for bioinformatic data interpretation and microbial hazard assessment.

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. We continue to foster new partnerships, increasing our social media presence via Twitter and updating and maintaining our website. Thanks to the IWR media team, and in particular, Mr David Forsyth and Mrs Margaret Wolff, for keeping our website regularly updated. We also focus on increasing our community engagement initiatives. The IWR staff and students attended a number of local and international conferences, including the Society for Freshwater Science conference in Brisbane Australia, attended by Prof. Odume, Dr Nnadozie and Dr Akamagwuna. The Africa Chapter of the Society for Freshwater Science organised a special session on Bioassessment in Africa. Through its work as the CoE, the Institute participated in the 4th ARUA Biennial International conference hosted at the University of Lagos which brought together all key ARUA stakeholders and partners. The work being implemented in the CoE was presented by Dr Jane Tanner and Dr Mathew Weaver at this conference.

I am deeply grateful to all staff, postdocs, students and Research Associates of the Institute for their continued support. I especially thank the IWR leadership: Prof. Sukhmani Mantel, Dr Jane Tanner and Dr Chika Nnadozie for their support.

Prof. O.N. Odume
Director, IWR

African Research University Alliance Centre of Excellence (CoE) in Water Director's Report

CoE hub: IWR, Rhodes University

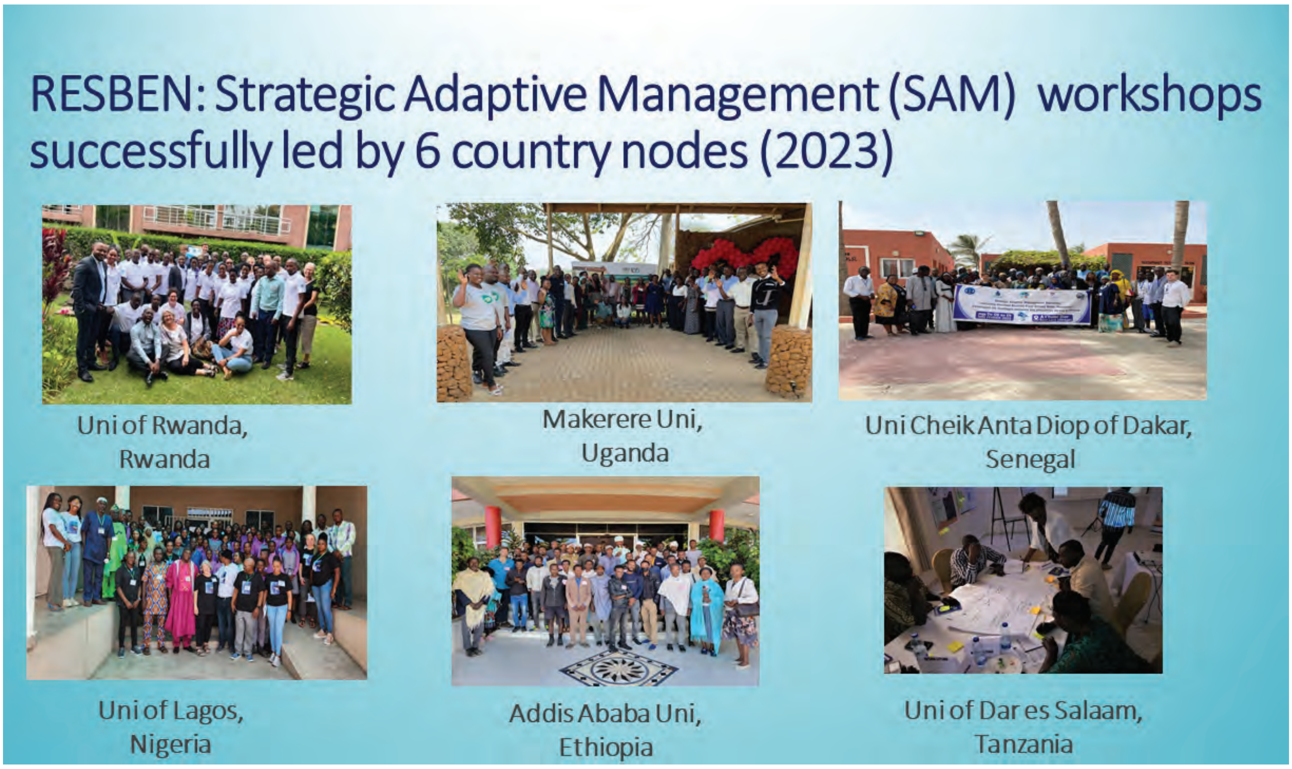
CoE nodes/partners: Makerere University (with Co-Director, Prof. Isa Kabenge), Université Cheikh Anta Diop, University of Rwanda, Addis Ababa University, University of Lagos, University of Dar es Salaam, University of Cape Town, University of KwaZulu-Natal.

The CoE's busy year has left us in a strong position going into 2024. Most of the year was spent wrapping up both United Kingdom Research and Innovation (UKRI) grants, and building foundations for 2024 in the form of publications and proposals. We are grateful to have the ongoing involvement of Emeritus Professor Tally Palmer who continues to be actively involved in the research carried out. The network has formed an extremely strong group of researchers committed to building the Water CoE.

Overview of the 2023 research within the CoE

Research is supported by two grants: the UKRI-funded Capacity Building grant (Water for African SDGs) which concluded in March 2023, and the UKRI-funded Research Excellence grant (Resilient Benefits for African Water Resources, RESBEN) which concludes in March 2024. Activities during 2023 included a series of workshops in our various partner countries: Senegal, Uganda, Ethiopia, Rwanda, Nigeria, and Tanzania. The workshops focused on building community capacity in Strategic Adaptive Management (SAM) around water governance.

Our Ugandan project partners hosted an integration meeting on the banks of Lake Victoria on the outskirts of Kampala, focused on transformation towards sustainability. The meeting critically examined and reflected on the sustainability research carried out during the project, questioning how effective or transformative our methods are, as well as how transdisciplinary, or integrated across disciplines they are.



Part of this meeting was dedicated to designing and committing to the preparation of a special journal issue, which the *Ecology and Society Journal* have agreed to publish. The paper authorships will be from across the network, so forming a strong foundation for the CoE in terms of future funding, reputation and partnerships. The special issue journal publications are expected to be submitted in 2024 and will build on an already published CoE network authored paper in 2023, led by Prof. Tally Palmer, which details the approach designed and utilised for the UKRI Research Excellence grant, RESBEN. The grant has led to the publication of a number of papers by students which focus on the specific work carried out by the various Research Assistants as part of the grant. This work was highlighted in a research webinar held online on 28 February 2023, which provided an overview of the six case studies and two learning sites included in the grant. [See the RESBEN project report for more detail.]

Researchers in the RESBEN project have developed new tools and methods: the adaptation of the Value Creation Framework, and the innovation of the "CSES Integration Wheel". Led by Dr Rebecka Henriksson, the "CSES Integration Wheel" improves the substantive integration required of complex social-ecological systems (CSES) research, addressing integration across academic disciplines; knowledge systems (academic and non-academic, including local traditional knowledge); and the science, policy and practice spheres, to ensure equitable impact and lasting change. One publication describing the tool development and one outlining the RESBEN Integration assessment are being prepared for submission during 2024.

To assess and showcase the impact of such transdisciplinary research – in addition to typical measures of project deliverables – Dr Matthew Weaver led the research into kinds of value developed for different participants in the RESBEN project. By adapting the Value Creation Framework and designing an extensive and iterative assessment of value over time, Weaver and team showed how the development of value for different actors in the RESBEN project led to the formation of collaborative, effective and informed transdisciplinary research teams. These relationships resulted in a deeper transformation, recognising the importance of including social science and engaging stakeholders in research. Node Co-Investigators deeply appreciated working together in a collaborative way. The presentations and discussions on value creation have sparked interest and led to the adoption of the approach in other areas and funding proposals.

Postdoctoral Fellows within the Institute played a key role in the innovative research across the case studies. Dr David Gwapedza worked with the Makerere University team, Dr Bukho Gusha worked with the Addis Ababa team, Dr Matthew Weaver worked with the University of Rwanda team, Dr Nolusindiso Ndara worked with the University of Lagos team, and finally two researchers, Dr Rebecca Powell and Dr Rebecka Henriksson worked with the University of Dar es Salaam and Université Cheikh Anta Diop, respectively. Two Postdoctoral Fellows have recently left the Institute to pursue exciting opportunities: Dr Bukho Gusha has taken up a senior lectureship position at the University of Limpopo, and Dr Nolusindiso Ndara has taken up a position with EFTEON. We wish them well and look forward to future collaborations.

Building on the strong foundation in CSES within the CoE built during Prof. Palmer's time as Director, Dr Rebecka Hendriksson, and Dr Matthew Weaver will take this research forward as CSES research leaders.

Networking events in 2023

Mrs Margaret Wolff and Dr Rebecka Henriksson represented the ARUA Centres of Excellence Directors' meeting hosted by the University of Mauritius on 23–24 February 2023 which brought together the Centre Directors and Managers of the 13 ARUA CoEs. Representatives of each Centre presented a self-assessment of achievements, challenges and future plans to share with ARUA and the other Centres. Mrs Margaret Wolff presented the work undertaken in the Water CoE in the last three years, and the Centre was praised for their work and the large number of Water CoE nodes they are working closely with. At the meeting the Secretary-General of ARUA, Prof. Ernest Aryeetey, presented feedback on the various activities that ARUA has been involved in over the past year. The meeting provided an excellent opportunity for the Centre Directors and Managers to meet in person, learn from one another's unique experiences and skills, and to discuss future collaboration ideas.

Drs Bukho Gusha, Matthew Weaver and Rebecka Henriksson from IWR, and Dr Prossie Nakawuka (Makerere University, Uganda), attended the Carnegie Corporation of New York (CCNY)-funded Early Career Researcher (ECR) Meeting in Pretoria in December 2022. The week-long event brought together around 80 early career researchers (ECRs) from more than ten African countries. The meeting enabled experiential learning and balanced ECR skills development sessions, informative talks and discussions, networking and mentor-led thematic working group sessions. The working groups developed and presented a realistic concept note addressing a particular global grand challenge, taking a transdisciplinary approach.

The 4th ARUA Biennial International Conference, hosted at the University of Lagos, Nigeria from 15–17 November, centred around "Reimagining the Future of Higher Education in Africa" and provided a forum for university leadership, thought leaders and researchers to engage in meaningful and passionate discussions on future sustainability scenarios and the quality of outputs from African universities. The CoE team – Dr Jane Tanner, Dr Matthew Weaver, student Ms Phatsimo Ramabatsana, and intern Ms Siphamandla Mjuleni – met Prof. James Akanmu, co-lead of the University of Lagos node, other CoE Directors from across Africa, and the University of Lagos senior management. The conference provided networking opportunities for Vice-Chancellors and Deputy Vice Chancellors from many of the ARUA Universities. At the conference, Rhodes University Vice Chancellor Prof. Sizwe Mabizela's appointment as incoming Chairman of the ARUA board in 2024 was announced.

The Water CoE presented three papers, and ran a CoE workshop for early career researchers (ECRs). Dr Tanner presented a paper co-authored by Dr Ana Porroche Escudero, on structural inequalities holding African researchers back; Dr Weaver presented a paper co-authored by Dr Henriksson, on the CSES Integration Wheel in the context of transforming higher education in Africa. He demonstrated how the tool could be used to design transdisciplinary research across the continent, effectively and equitably addressing pressing sustainability challenges. Dr Weaver also presented a paper on his value creation framework and how it was used to uncover hidden value within the RESBEN project. Although the audience was small, both Prof. Ernest Aryeetey, Secretary General of ARUA, and Prof. Linda Mtwisha, Executive Director of Research at University of Cape Town, attended the presentations and engaged in the discussions that followed. The CoE workshop was a success with many ECRs from other nodes. The team conducted an interactive workshop for the ARUA CoE Water, using the River of Life reflection approach which provided participants with a creative, distinctive approach to sharing and reflecting on their academic experiences, culminating in the creation of collective visual representations of significant moments in their individual journeys.

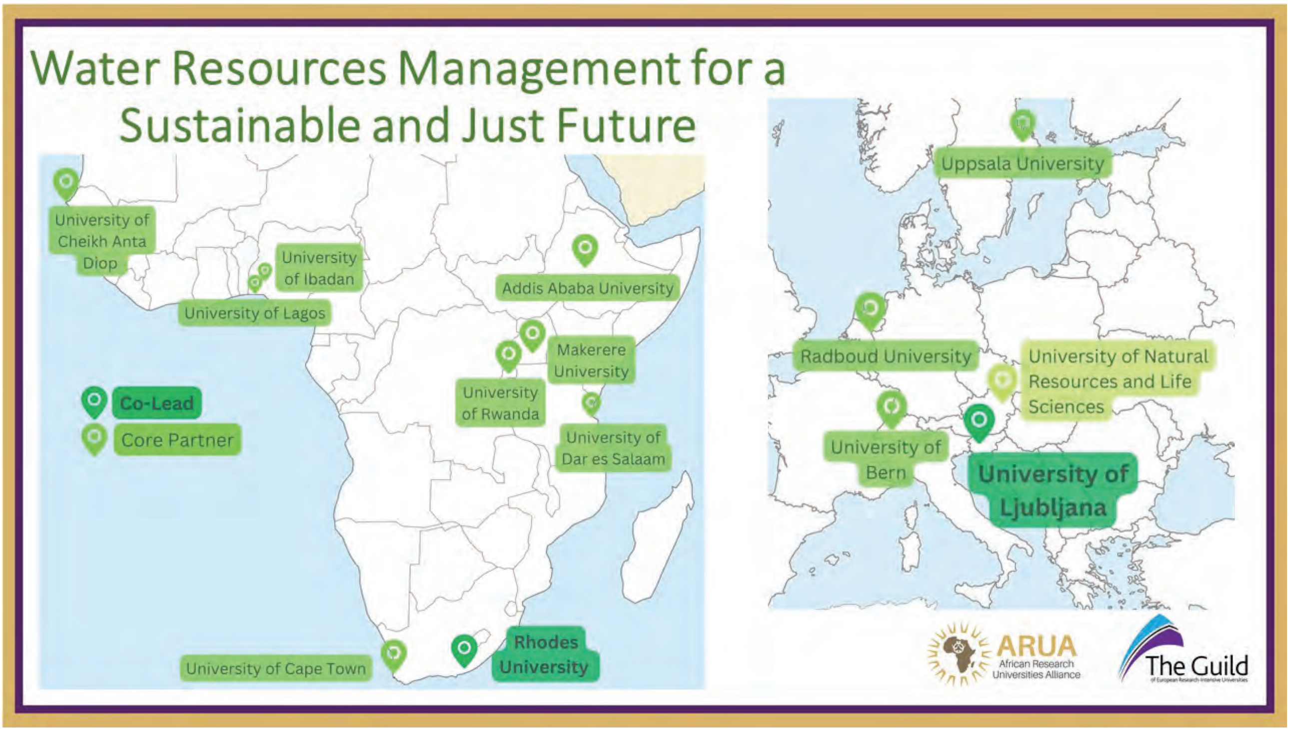
Dr Tanner has been working closely with the CoE in Notions of Identity based at Makerere University, assisting them with the administration of their UKRI Capacity Building grant. In September, she ran a grant writing course for the CoE and its ECRs which was well received; she continues to support the CoE by reviewing proposals.

Looking forward to 2024

Dr Djim Diongue from Water CoE node Université Cheikh Anta Diop, Dakar, Senegal, was awarded the ARUA-Carniegie Early Career Research Fellowship Award and will be placed at the IWR as a postdoctoral researcher for one year from October 2023. During his time there, he will work with other researchers at the Centre, writing and publishing academic journal papers and assisting in other Water CoE activities, including the RESBEN work associated with the Senegal CoE node. The Centre is delighted to host Djim during this time; he has been an engaged team member in the Water CoE, and received the award for the best PhD thesis in Senegal 2023.

The CoE has been very active writing proposals to ensure the sustainability of the CoE after the conclusion of the UKRI grant support. As a CoE we have held regular sustainability meetings online to discuss funding opportunities and the teams that will apply. We will continue these in 2024 to ensure the Water CoE continues to grow and work together, and becomes a self-sustaining Centre. Over 2022/2023, we have written 12 international grant applications, and I sincerely commend the full CoE team for the tremendous hard work they have invested in these grants. Of these twelve, six have been unsuccessful, we are waiting to hear about three, but have had three successful applications.

Firstly, Prof. Sukhmani Mantel, the Academic Manager of the Water CoE, has been awarded an Erasmus Plus grant as project lead. This proposal focuses on capacity building and curriculum/course development in the field of Nature-based Solutions (NbS). The consortium team consists of two universities in South Africa (Rhodes and Cape Town), two universities in Senegal (Ecole Polytechnique of Thies, Université Cheikh Anta Diop), and three partners in the EU: TU Delft (Netherlands), AgroParisTech (France) and INRAE (France). The project will build upon the African Water Resource Mobility Network (AWARMN) for sharing knowledge. The grant supports the time of three researchers, the research development manager, and a postdoctoral fellow, and represents a significant support for the CoE for the next three years.



Secondly, ARUA has established a close partnership with The Guild of European Research-Intensive Universities, at the heart of which has been a joint appreciation to address global challenges affecting the African and European continents much more effectively by developing new, long-term partnerships based on equity. A call to host Clusters of Excellence was released and the ARUA CoE and IWR partnered with the University of Ljubljana in Slovenia, proposing a Cluster of Excellence titled "Water Resource Management for a Sustainable and Just Future". We were particularly thrilled to be awarded this new Cluster of Excellence and look forward to fruitful research with our large team of partners.

Thirdly, the ARUA Board approved the selection of six ARUA Centres of Excellence to be awarded grants for the design of Pilot Collaborative PhD Programmes. The selection was based on the assessment of proposals submitted by nine of the 13 ARUA CoEs, scored by ARUA DVCs for Research. The selected CoEs will receive a grant of $5,000 to be used in engaging consultants/resource persons in the design of collaborative PhD Programmes, which will be reviewed and accepted by the ARUA Board at their meeting scheduled in May 2024. This award highlights the continuing success of the Water CoE within the ARUA network.

Lastly, I offer profound thanks to UKRI for their support over the past few years which has enabled the Water CoE to flourish and grow. Additional thanks to Rhodes University who have always supported the CoE. Finally, a huge "thank you" to the researchers and support staff involved in the CoE research over 2023. Everyone has gone above and beyond to ensure that we have delivered world-class research, and built a strong CoE going forward. I am sincerely grateful.

Dr Jane Tanner
ARUA Water CoE Director

Centre for Environmental Water Quality report

The Centre for Environmental Water Quality (CEWQ) has continued its pursuit of excellence in the use of aquatic ecotoxicology and microbial ecology tools to address critical issues in environmental water quality, ecology, One Health, and water governance. The Centre is committed to bridging the gaps between these areas, fostering a comprehensive understanding of the intricate relationships between aquatic ecosystems, human health, and effective water resource management. Our diverse team has made substantial strides in advancing knowledge and addressing key challenges in Water Quality and Human Health, Ecosystem Services, Community Resilience, Policy and Governance for Water and Health, Climate Change and Health Impacts.

Throughout this year 2023, the Centre has achieved remarkable milestones. From ground-breaking discoveries published in leading peer-reviewed journals to securing substantial funding for innovative projects, our collective efforts should make a lasting impact on the landscape of Environmental Health and EcoHealth. In 2023 alone, the Centre researchers were awarded at least R5 400 000 in funding from the Water Research Commission of South Africa plus a yearly R200 000 Self-Initiated Research Grant, from the South Africa Medical Research Council for the next four years. Thanks to the generous support of the Water Research Commission, South Africa and the South Africa Medical Research Council, we continue to acknowledge and express gratitude for the financial support received from other existing funding sources of our ongoing projects: Intra-Africa Academic MEducation and of the European Union, funding the African Water Resources Mobility Network (AWaRMN) project (€1.39M) led by Prof. Odume, the European Union and Fondation Botnar funding, the European and Developing Countries Clinical Trials Partnership (EDCTP) project (€150 000), led by Dr Chika Nnadozie, and Belmont Forum funding for the SDG pathway project partners IIASA, GAIA, INRAI (Montpellier University), Government offices of Sweden, Federal Ministry of Education and Research.

These funds have been allocated to support the following diverse projects:

- Equity dimensions of the Nelson Mandela Bay water crisis and the implementing context as enabler or barrier for uptake of translatable lessons from the Cape Town Water crisis;
- Governance and institutional arrangement for accelerating equity in the water-land-agricultural nexus; a case study of resource-poor farmers/ emerging farmers in smallholder irrigation schemes in the lower Sundays River (Barkley Bridge) and Great Fish River (Tyhefu) Catchments;
- Revision of the 1996 South African Water Quality Guidelines: developing a risk-based approach using aquatic ecosystems responses;
- Development of long- and short-term technical solutions, mitigation measures and decision support strategies that will improve water quality in the Grootdaai Dam Catchment;
- An integrated approach to timely detection and prevention of waterborne zoonoses outbreaks in selected municipalities of the Eastern Cape, South Africa;
- The application of environment, animal and human disease surveillance for early detection and prevention of bacterial zoonoses from a selected source water in Eastern Cape;
- The multiple risk dimensions associated with Campylobacteriosis – a key poverty-related disease of South African urban source water environments;
- Sector programme water policy – innovations for resilience (WaPo-RE);
- African urban complexities and the governance challenges of urban rivers;
- SDG-pathfinding: Co-creating pathways to sustainable development in Africa, funded by the National Research Foundation;
- Cyanobacteria – the missing link in vibriosis dissemination;
- Economy and agriculture in Southern Africa, funded by ECWASA, BMBF

These investments have already yielded significant outcomes, including at least 10 published peer-reviewed research papers, five under review, at least 10 research project deliverables, and four MScs completed and graduated this year. Congratulations to our 2023 MSc graduates: Mr Andrew Ali Abagai, Ms Nandipha Ngoni, Ms Zintle Mtintsilana and Ms Noleen Tavengwa. Looking ahead, the funding received in 2023 positions our Centre for continued success by providing a solid foundation for upcoming projects, ensuring our commitment to impactful research.

Collaboration has been a cornerstone of our success this year. We are proud to have established impactful partnerships with the Bayreuth University-led Africa Multiple Cluster of Excellence initiative, with Prof. Odume as the Academic Coordinator; with the Council for Scientific and Industrial Research, South Africa; the Centre for Agricultural Transformation, Malawi; the Durban University of Technology; Mercedes-Benz Manufacturing South Africa Ltd, East London; the University of Hohenheim, Institute of Agricultural Sciences in the Tropics; the Institute for Water and Waste Management at RWTH Aachen e.V.; TZW:DVGW-Technologiezentrum Wasser; the University of Stuttgart; the Department of Water and Sanitation, Republic of South Africa; the South African Institute of Aquatic Biodiversity (SAIAB); SEBA Hydrometrie GmbH & Co; KG, AUTARCON GmbH, Gemeinde Ilsfeld; Barthauer Software GmbH; Chris Swartz Water Utilization Engineers; Kouga Local Municipality; Amatola Water; the Australian River Institute; the University Joseph Ki-Zerbo Ouagadogou; the Swedish Research Council; Stockholm University; Scientific Research and Technological Applications, and Makerere University. We extend our sincere thanks to each of our partners for their commitment to our shared goals and to fostering a dynamic exchange of ideas and resources that has elevated the scope and impact of our research.

Impact on the Community:

Beyond the confines of academia, our research group has actively engaged with the community through activities such as the Centre for Environmental Water Quality (CEWQ) annual school learner biomonitoring and awareness-raising programme. By promoting awareness and understanding of our research, we aim to bridge the gap between scientific inquiry and societal impact.

Acknowledgement to CEWQ team:

Our success is a testament to the hard work, dedication, and expertise of each team member. We extend our sincere appreciation to every individual who has played a role in our collective journey, shaping the trajectory of our research.

As we reflect on the accomplishments of the past year, we look forward to even more exciting discoveries and advancements in the coming year. Our team is poised to tackle new challenges and contribute further to the ever-evolving landscape of Environmental Health and EcoHealth.

Dr Chika Nnadozie
Centre of Environmental Water Quality Head

Hydrology research group report

Another busy year for the Hydrology group has left us in a strong position going into 2024. Most of the year was spent wrapping up three Water Research Commission (WRC) grants which conclude in March 2024, and running a fourth WRC project which concludes in 2025. Ms Phatsimo Ramatsabana graduated with an MSc in Hydrology in April 2023, on her research into surface water and groundwater interactions in Lake Sibaya. Two further students, Mr Peter Wasswa and Mr Kamva Zenani, submitted their MSc research theses (Peter's is concluded; he will graduate in April 2024; Kamva's thesis is under examination). We are grateful for the involvement of Emeritus Professor Denis Hughes who continues to be actively involved in the research carried out. The Hydrology group has formed a small but solid group of researchers and will be joined by IWR Research Associate Dr Julia Glenday who will assist with publication of the backlog of papers from the Hydrology research.

Overview of the research from 2023

A continuously growing area of research for the Hydrology group has been research into socio-hydrology, and a number of grants have been awarded focused on continuing research around water contestation issues (led by postdoctoral fellow Dr David Gwapedza). Research which continues the work started by Prof. Hughes is research into modelling uncertainty and risk, particularly focused on model structural uncertainty (led by Research Associate Dr Julia Glenday). Postdoctoral fellow Dr Bukho Gusha leads a project in rangeland management, and Associate Prof. Sukhmani Mantel, together with Prof. Tony Palmer lead a project on the water use of Cannabis for legacy farmers in the Eastern Cape.

In 2023, the culmination of the Koue Bokkeveld (KBV) project marked a significant milestone, with extensive efforts dedicated to consolidating and documenting the project's activities spanning its entire duration. Noteworthy achievements were realised in the areas of collaboration, dissemination, and stakeholder engagement. This project collaborated with Dr Olivier Barreteau and Dr Bruno Bonte of INRAE, France; Dr Bruce Paxton of the Freshwater Research Centre, and Prof. Karen Bradshaw from the Computer Science Department at Rhodes University. The support that the IWR team received from all the partners has been extraordinary, and I express my gratitude for this. Although challenging, the project has been immensely successful. A significant

collaborative effort during a joint-working session with team members at INRAE, France, involved Prof. Bradshaw, students Sinetemba Xoxo and Rodney Tholanah, and resulted in an Agent-Based Model (ABM) and a Role-Playing Game. These outputs were subsequently used in a co-planning workshop with stakeholders. We have also had a number of visits from Dr Olivier Barreteau (the most recent in August 2023), who continues to be an invaluable support to the team.

The closure of the 'Koue Bokkeveld Water Workshop Series' took place in November 2023, marked by a final workshop. Mr Rudolph Roscher from the Western Cape Department of Agriculture-LandCare proposed presenting the project's models and overall work to Water User Associations (WUAs) in the province, and he offered to facilitate this presentation, providing crucial validation for the practical application of the project's outcomes in catchment management. This invitation coincided with plans for a final dissemination workshop scheduled for May 2024, aimed at stakeholders beyond the KBV project. We are actively pursuing additional funding to advance our work in the region. Dr Gwapedza, in collaboration with the University College Dublin, has successfully secured an ARUA/U21 grant which will enhance the representation of the SWAT hydrological model in the study area, a critical component for comprehending and managing water resources effectively.

A WRC project has examined modelling uncertainty in light of the risks associated with making decisions based on model outputs; it is critical to quantify the uncertainty within these outputs. As reliance on modelling grows, so too should attention to model uncertainty: quantifying it, finding practical ways to reduce it, and accounting for it in decision making. The project held a 'model-a-thon' to explore how differently individual modellers are likely to set up and calibrate a catchment model when given the same brief and input data, and to understand how much these differences influence the modelled predictions and what this means for uncertainty. The activity was open to anyone interested, publicised via the South African Hydrological Society (SAHS) as a formal workshop at the SAHS Conference 2022, with the goals of connecting the modelling community and fostering discussion around uncertainty. The student prize of this competition was won by one of IWR's PhD students, Mr Sinetemba Xoxo.

This project also synthesised uncertainty research findings with the help of water sector professionals to develop a policy brief on modelling uncertainty that accounts for the practical hurdles faced in this field. This brief can be used to promote and gather support for the activities needed to consider and to reduce model prediction uncertainty. Lastly, project activities included working on, and promoting, two online resources that facilitate information exchange and capacity building across the hydrological modelling community: an editable 'wiki' website on hydrological modelling tools (https://hydromodel-sa-wiki.saeon.ac.za/) and the pre-existing online 'question-answer' (Q&A) platform 'Stack Exchange', specifically the Earth Science subsite (https://earthscience.stackexchange.com/).

The Cannabis project led by Dr Sukhmani Mantel and Prof. Tony Palmer, 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 are being determined through field-based trials and pot experiments, which continue to support the IWR's investment into water-use measurement equipment, the scintillometer and eddy covariance. The project is collaborating with two new partners. Dr Garth Cambray of Makana

Meadery, who is interested in connecting resources with sustainable development and technology transfer opportunities through value of cultural capital, land, biodiversity resources. The second new partner is Prof. Joanna Dames, a mycologist in the Department Biochemistry, Microbiology and Biotechnology at Rhodes University.

The Rangelands Management Project, under the leadership of Postdoctoral Fellow Dr Bukho Gusha, has focused predominantly on intensive data analysis, comprehensive writing, and limited fieldwork. The project achieved significant milestones, particularly in the realm of capacity building. A notable accomplishment was the graduation of three Honours students in 2023. Among the graduating students, Ms. Asisipho Kinkwayo has embarked on a Master's degree in Environmental Science under the joint supervision of Prof. Charlie Shackleton and Dr Gusha, highlighting the collaborative mentorship approach that characterised the project.

After the successful training in Dr Andrew Slaughter's WQSAM water quality model for the Department of Water and Sanitation (DWS) in 2021, the Department has again approached us to provide training on WQSAM for a new team working on revising the Waste Water Treatment Standards within the DWS. This represents a growing collaboration between the IWR and DWS in terms of capacity-building initiatives. Dr Andrew Slaughter, Dr David Gwapedza and I will carry out the training, in conjunction with IWR Research Associate Dr Patsy Sherman.

Rhodes University has commissioned the IWR to undertake a Water Management Plan for the University, to ensure that the University works towards a sustainable supply of water, and is prepared for municipal supply issues and droughts in the future. Dr Rebecca Powell and I are leading this work, which builds on a long-term data collection initiative by the Hydrology group.

Networking events in 2023

The Institute for Water Research (IWR) actively engaged in the 9th Global FRIEND-Water International Conference, in Dakar, Senegal from 25–30 September, reaffirming its commitment to sharing knowledge and advancing collaboration in the field. Dr Gwapedza presented a socio-hydrology paper, shedding light on best practices in stakeholder engagement. Simultaneously, Dr Tanner contributed a paper that explored the impacts of climate change on environmental flows or Environmental Water Requirements (EWR).

Participation in this conference served as a platform for IWR to strengthen its presence as a key player in the FRIEND and IAHS-Africa network within the Southern African region. Beyond the presentation of research findings, the conference facilitated networking opportunities, fostering connections with other leading experts and institutions in the field. Building on its commitment to global water-related initiatives, IWR took a significant step by pledging to co-lead UNESCO-IHP hydrology working themes which specifically concentrate on enhancing data availability and exploring the intricate dynamics of socio-hydrology. By spearheading these initiatives, IWR positions itself as a frontrunner in the pursuit of cutting-edge research and practical applications in the realm of water science, solidifying its role as a key contributor to international hydrological advancements.

PhD student, Mr Sinetemba Xoxo presented a paper at the International Conference on Decision Support System Technology (ICDSST), in Toulouse France, focused on his PhD research into a Water Sharing Model which examines alternative ways to share water during deficits, and in particular the inclusion of equity into the water sharing process. This presentation further enhanced the KBV project's visibility on an international platform.

Looking forward to 2024

I have been invited to be on the International Scientific Council of the UNESCO ICIREWARD (International Centre for Interdisciplinary Research on Water Systems Dynamics) based in Montpellier, France, and I serve on the advisory boards of the hydrological arm of EFTEON (The Expanded Freshwater and Terrestrial Environmental Observation Network), and the of the ARUA Centre of Excellence in Notions of Identity based at Makerere University. Dr Mantel and I serve on the Environmental Committee at Rhodes University.

The Hydrology group has submitted four WRC proposals and two international UKRI proposals. Should any of these proposals be successful, they would start early in 2024. The group has also committed to focusing heavily on publications in 2024 as the publication backlog from the last few years of research is growing. Part of this drive is supporting Dr Julia Glenday, who has been involved in IWR hydrological research for a number of years. The new ARUA Postdoctoral Fellow, Dr Djim Diongue from Water CoE node Université Cheikh Anta Diop, Dakar, Senegal, is a hydrogeologist, so we look forward to a revitalisation of our work into groundwater dynamics.

I am immensely proud of the hydrological team for their commitment and support in 2023, and I look forward to 2024 and more exciting research emerging.

Dr Jane Tanner
Hydrology Group Research Head

Community Engagement

Ms Khaya Mgaba leads the Institute for Water Research (IWR) Citizen Science Group with the help of IWR staff members, Dr Chika Nnadozie, Dr Rebecca Powell and Mrs Margaret Wolff, with postgraduate students, Ms Mary Chibwe, Mr Andrew Ali, Mr Miracle Osoh and Mr Siyabonga Mazibuko, and Presidential Employment Stimulus (PES) interns, Namhla Mqoqi, Sinalo Kinzela and Siphamandla Mjuleni.

The IWR hosted Top Science Achievers from various high schools in Makhanda. The learners were given an overview of the African Research Universities Alliance (ARUA) water Centre of Excellence (CoE) work using digital stories of African water challenges and water scarcity and the need to look after freshwater resources. Attendees learned how the health of people is closely linked to the health of animals, plants, soil, water and the environment in general, and how to prevent waterborne diseases. A demonstration of Mini-SASS showcased the value of water resources and how resident biota respond to changes in water quality. The learners also had the opportunity to learn important macroinvertebrate identification skills.

(Above)Top Science Achievers from - Kutliso Daniels, Graeme College, Ntsika Secondary School, Victoria Girls High School and Mary Waters High School; (Below) IWR staff members and postgraduates.

Grade 7 learners at Fikizolo are at that exciting stage for learners, when they are preparing to join high school. This is a very important stage for most of them to begin deciding what they want to be in future. The IWR Citizen Science group was there to guide the learners about water-related careers that they can follow, and to demonstrate how to monitor the ecological health of water resources using freshwater organisms.

Ms Khaya Mgaba with the Interns at Fikizolo Primary School career fair.

Capacity building

The IWR had the privilege of hosting three PES interns for six months. Namhla Mqoqi holds a BSc in Microbiology, Siphamandla Mjuleni holds BSc in Social Science and Sinalo Kinzela, a BSc in Chemistry. They have been exposed to the different units of the Institute for Water Research: Hydrology, Water Quality, Microbiology and Community Engagement.

From left: Namhla Mqoqi, Siphamandla Mjuleni and Sinalo Kinzela

Project reports

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

D. Gwapedza, J.L. Tanner and S.K. Mantel
Collaborators: B. Paxton (FRC, South Africa), O. Barreteau (INRAE, France), B. Bonte (INRAE, France)
April 2021 – March 2024

Sponsor: Water Research Commission

The project engaged a group of heterogeneous stakeholders (primarily farmers) in the Koue Bokkeveld (KBV) to co-develop a shared water management plan based on a shared understanding of the water challenges in the catchment. The project recognised the catchment challenges, including dry season water conflicts that sometimes spill into the courts. Unfortunately, water users' disputes over access to the resource rarely consider the environmental water requirements. If left unmanaged, a potential loss in agricultural productivity could occur, affecting food security and the livelihood of the thousands of farmworkers who work in the area. Effective water management is vital to ensure equitable water access to foster shared growth, reduce water conflict, promote ecosystem health, and prevent biodiversity loss. This project's 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 and water availability under growing agricultural development and climate change in order to adapt the water management plan to anticipated scenarios to ensure sustainability.

A mixed-methods approach was adopted in this research following multiple disciplines to fulfil the project aims: hydrological, ecological, social, and computer sciences. Hydrological and ecological data were used to set up an Agent-Based Model (ABM) (branch of computer science), as the principal tool for negotiation support for the stakeholders. Social science principles were adopted in stakeholder engagement through various methods that included workshops and interviews.

Three institutions collaborated on the project: the Institute for Water Research-Rhodes University (IWR-RU) South Africa, specialising in hydrology and water governance, led the project; the Freshwater Research Centre (FRC) in 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 for three years and involves three post-graduate students: Mr Sinetemba Xoxo (PhD), Mr Sakikhaya Mabohlo (MSc), Mr Rodney Tholanah (MSc) and Ms Njabulo Dlamini (BSc Hons).

Progress

Three participatory workshops with the stakeholders have been carried out. The first was an introductory workshop co-hosted with the World Wildlife Fund. The other two workshops were participatory modelling workshops where we elicited information from the stakeholders to construct models and present prototype models to farmers for verification. Various models have been applied in this work: some classical models, such as Pitman and the Soil Water Assessment Tool (SWAT), and some novel approaches. The cocktail of models was used in response to the heterogeneity of the stakeholder group; the various tools would thus be able to meet the various demands.

The modelling work was implemented as a series of student projects. A detailed process-based hydrological SWAT model was set up for the catchment. Data for implementing SWAT was gathered from local and international databases. While impressive performance was achieved with the model, significant gaps in the model structure constrained our representation of other key processes. We have now secured short-term international funding by ARUA-U21 to expand the representation of processes within SWAT, and have partnered with Dr Sonam Dash of the University College Dublin for this work.

Figure 1. A project team workshop planning meeting in the KBV.

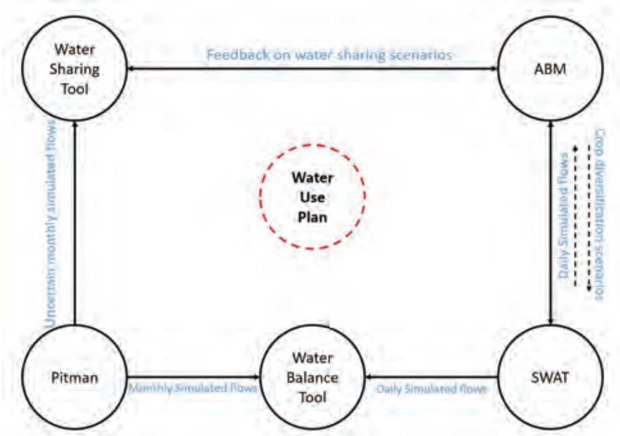


Figure 2. The various tools used in the project and how and the feedback between them.

The water allocation/sharing tool which assists stakeholders in managing water resources equitably under uncertainty is at an advanced stage. Because these concepts are not easy to communicate to a group of non-scientific stakeholders, PhD student, Mr Xoxo, has developed a game to communicate and co-simulate various management scenarios with stakeholders, following research training visits to INRAE, where Dr Barreteau and Dr Bonte assisted him. MSc student, Mr Tholanah, has also developed the ABM tool under the principal supervision of Prof. Karen Bradshaw of the Rhodes University Computer Science Department and with support from our INRAE colleagues.

The ABM model and the water allocation tool will be applied at our next stakeholder workshops. The tools will be used to demonstrate to stakeholders the pathways and possibilities of equitable water management and can be a basis for negotiating water sharing based on water supply and use scenarios.

All students are in the advanced stages of their projects, as described in their student reports. Students are registered across several academic departments at the University, indicating the interdisciplinary and collaborative nature of the project.

Interest in the project has been widespread, with some notable support and interest in the project from the Western Cape Department of Agriculture, from the World Wildlife Fund, and farmers from other regions.

We disseminated the project work extensively in South Africa and across the globe. Project team members from the collaborating institutions have shared the work at various conferences and symposia. This year, the project work was shared at three conferences held in South Africa, France, and Senegal. We have produced several research reports for the WRC, NRF and other funding organisations, including the Oppenheimer Memorial Trust and Rhodes Research Office. One publication has been published so far, and we have another under review. We plan to publish many other papers from this work.

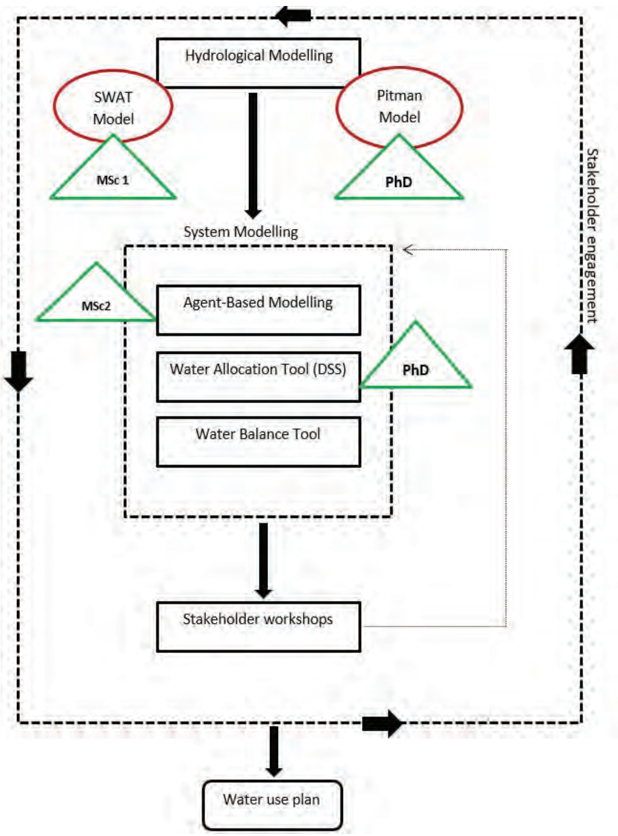


Figure 3. An illustration of the conceptual framing of the project implementation.

The African Water Resource Mobility Network (AWaRMN)

Partners: Rhodes University, South Africa; University of Kinshasa, Democratic Republic of Congo; Federal University of Technology, Nigeria; Makerere University, Uganda; National School of Hydraulics, Algeria; TU Delft, The Netherlands (technical partner).
Reporting period *January 2023–November 2023*

Sponsor The Intra-Africa Academic Mobility Scheme of the European Union

Background

The African Water Resources Mobility Network (AWaRMN) is a multi-partner project of the EU-funded Intra-Africa Academic Mobility Scheme which aims to foster collaboration and cooperation between higher education institutions in Africa in the water research sector through mobility in Africa. The overall objective is to enhance human capital development in Africa, while strengthening intra-African cooperation in higher education as called for by Agenda 2063. The specific objectives of AWaRMN are:

- to increase the number of highly qualified and competent (MSc and PhD) graduates in the field of water resources in Africa;
- to build and sustain teaching and research capabilities among partner institutions;
- to design and implement research programmes based on collaboration and cooperation;
- to facilitate student and staff mobility to promote multiculturalism and internationalisation among African HEIs;
- to contribute to innovation and water technologies that advance social-economic development in Africa;
- to enhance professional career development and employability of graduates.

The project, initiated in 2019, is a collaboration between five partner institutions on the continent. To date, the project has successfully supported 32 MSc students, 12 PhD students and 12 academic and administrative staff on exchange programmes.

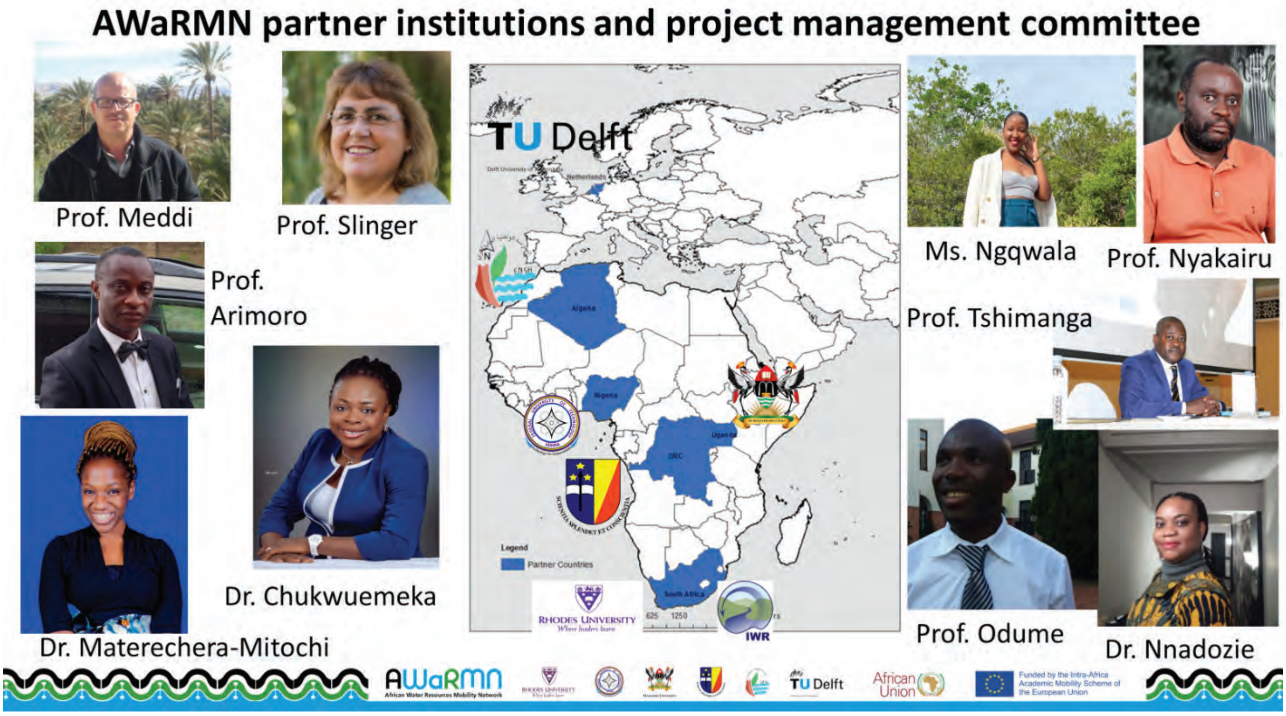


Figure 1. Current project management committee

2023 Overview

The year 2023 was marked with significant achievements within the AWaRMN community with several scholarship holders on degree seeking mobility completing their qualifications, student and staff mobility to additional countries beyond the AWaRMN partner institutions, the highest recorded number of staff mobility since the inception of the project, and the European Union recognising the network among the flagship projects within the

Intra-Africa mobility scheme. Table 1 provides a summary of selection results for mobility at the close of 2023, indicating a fair gender distribution of mobility amongst students that were selected to receive AWaRMN scholarships. The skewed gender distribution in numbers for staff mobility reflect the challenge of family responsibilities hindering African female academics from committing to extended periods of mobility. This constraint has been earmarked as a recommendation to the European Union for future mobility-related funding opportunities.

Table 1. Quantitative summary of selection results for 2023-2024

Type of mobility		Total number of persons on mobility	Gender of selected persons	
			Female	Male
Credit seeking		13	6	7
Degree seeking		8	4	4
Staff	Academic	9	7	2
	Administrative	2	0	2

In terms of mobility within the five partner institutions, Table 2 provides a summary of mobility as of November 2023 and indicates that all partners participated in mobility of both staff and students. AWaRMN's management committee expanded its membership through the addition of a full-time project administrator in March 2023, Ms Balisa Ngqwala, who is based at the IWR and attends to the overall administration of the project across the network.

One of the AWaRMN partners, Makerere University, was selected for a site visit by the European Union as part of the Mid-term evaluation of the Intra-Africa Academic Mobility Scheme. The site visit took place in July 2023 and involved interviews with AWaRMN co-ordinators and scholarship holders at the institution. Feedback from the evaluation was highly positive with AWArMN being marked as one of the top performing Intra-African projects. A quality assessment of the AWaRMN website was conducted by the European Union in October and received positive feedback. The website can be accessed at: https://www.ru.ac.za/intra-africa-awarmn/. AWArMN launched a structured, moderated Narratives of Hope talk series aimed at engaging leading African academics to share with our students their journey: how they started; how they got to where they are; the success stories; the challenges; and their best advice to future academics. The talk series specifically targets early career researchers. The first session of the Narratives of Hope series, a hybrid session, took place on the 23 July and profiled the academic journey of Prof. Tally Palmer.

Table 2. Summary of mobility in 2023 and expected in 2024 by partner institution

University	Staff mobility		Student mobility	
	2023	2024	MSc	PhD
Rhodes University	2	2	6	4
FUT, MINNA	1	1	4	2
Makerere	2	1	5	2
UNIKIN	1	1	4	2
ENSH University	1	1	3	1
Total	7	6	16	11

Sustainability initiative

AWaRMN will be moving into its final year in 2024 and the project management committee has established an impact and sustainability committee from among its members to plan for the sustainability of the network beyond the completion of the project and its associated funding. A sustainability strategy has been developed which involves the transition of the network into a collaborative platform with partnership beyond the institutional partners that currently constitute the network. A workplan is scheduled for the first quarter of 2024 in Uganda to translate this strategy to action.

Highlights within IWR

Among AWarMN achievements in 2023 one of the project's scholarship holders on mobility from the Federal University of Technology in Nigeria, Andrew Ali, completed his MSc in Water Resource Science from Rhodes University through the IWR and graduated with distinction in October 2023.

Figure 2. Andrew Ali and Prof. Odume at Andrew's graduation ceremony 13 October 2023.

Figure 3. Narratives of Hope flyer first talk series on the 26 July 2023.

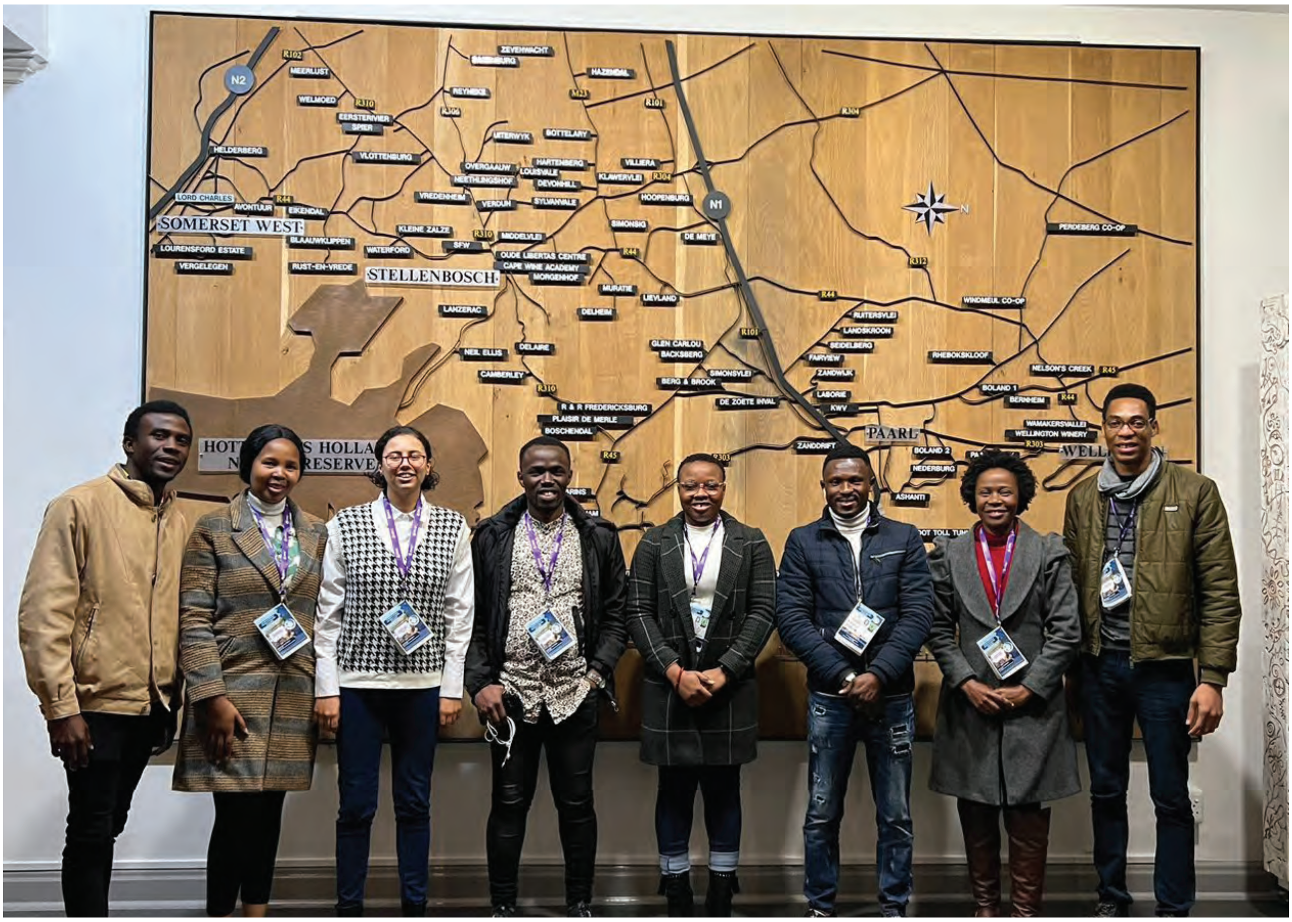


Figure 4. IWR and AWaRMN scholarship holders attending the 60th Annual Congress of the Southern African Society of Aquatic Scientists (SASAqS) in June 2023 in Somerset West, South Africa. AWaRMN scholarship recipients from left to right: Andrew Ali (Nigeria; MSc), Khaya Mgaba (Staff, on mobility to Nigeria), Sofia Lazer (Algeria; MSc), Enahoro (Nigeria; PhD); Esther Seriki (Nigeria, MSc); Frank Akamagwuna (PostDoc); Mary Chibwe (Zambia; PhD), Miracle Osoh (PhD).

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

B Gusha and D. Gwapedza
Collaborators: O. Gwate (University of Free State)
April 2022 – March 2024

Sponsor: Water Research Commission

This project used biophysical and social dynamics for livelihood advancement in the socio-ecological systems to understand the landscape for improved ecosystem services. Within this project, we assessed rangeland integrity (productivity and degradation) using ecosystems assessment and modelling methodologies. We conducted a community assessment on perceptions of the rangelands' importance as an ecosystem service provider, and management of rangeland. We coalesced findings from the scientific and social assessment to propose rangeland management practices, which will be shared with the community through our project partner, Lima. As part of the project, we encouraged communities to form a livestock association that manages grazing, livestock care and market-related information. The aims of the project were to:

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 livelihoods.
4. To facilitate rangeland management practices (plans), propose the formation of livestock associations, and the reinstatement of traditional rangeland management practices.

Two institutions collaborated on the project: the Institute for Water Research-Rhodes University (IWR-RU) South Africa and the University of Free State with researchers specialising in rangeland ecology and hydrology. This is a two-year project, ending in March 2024. Within the Project, three Honours students (Ms Asisipho Khinkwayo, Ms Esihle Gotye and Ms Dikeledi Phooko) have graduated and one MSc student (Ms Regina Nokufa Dakie) is in the process of completing her thesis.

Progress:

All the project activities – fieldwork, workshops, and student supervision – have been completed. Having graduated three students in this two-year project, the final integrated report is due.

Asisipho Khinkwayo and Dikeledi Phooko conducted workshops and one-on-one interviews to delve into local perceptions on rangeland provisioning ecosystem services, while Esitye Gotye conducted a hydrological modelling of a SWAT-based water balance assessment. Ms Dakie continues to contribute to the project, providing insight into the vegetation dynamics across the catchment.

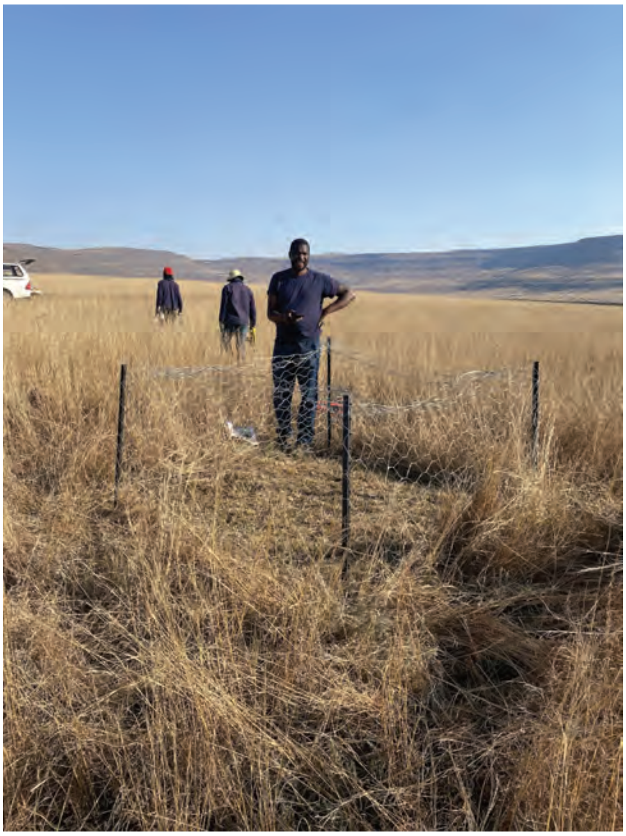


Figure 1: A grazing enclosure established in the Tsitsa River Catchment.

Determine water use of the cannabis plant in the Eastern Cape and KwaZulu-Natal provinces

S.K. Mantel
Collaborators: A.R. Palmer (IWR), S. Gokool (UKZN), A. Clulow (UKZN), K. Chetty (UKZN), S. Tesfay (UKZN), T. Mabhaudhi (UKZN), R. Kunz (UKZN)
April 2021 – March 2025

Sponsor: Water Research Commission

Interest in *Cannabis sativa* as a feasible, high-value crop for emerging small-scale farmers is expanding. *Cannabis sativa* is a multipurpose 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.

Cannabis research in African countries shows its importance to livelihoods

The proposed 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. The 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 needed 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 occurs. The aims of the WRC project are:

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*.
5. 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, one deliverable was submitted, and the second is planned for November submission, to the WRC:

Deliverable 5 (Progress report on the water-use estimates)

This deliverable partially addresses aim 3 of the project: 'Determine the water use and yield of *Cannabis sativa* for either fibre or oil production using field-based measurements'. The report provided a description of pot-based trial designs and initial results obtained, along with a description of field sites, equipment installation and initial results through the research of the three project-supported MSc students:

- Kamva Zenani, registered at the IWR, Rhodes University: Project title, 'Aspects of the water use of *C. sativa* under dryland and tunnel cultivation in the Eastern Cape'.
- Gary Denton, registered at Centre for Water Resources Research (CWRR), University of KwaZulu-Natal (UKZN): Project title, 'Water use of *Cannabis* trees in KwaZulu-Natal province'.
- Sindiswa Mbelu, registered at Centre for Water Resources Research (CWRR), University of KwaZulu-Natal (UKZN): Project title, 'The water use and water-use efficiency estimation of *Cannabis sativa L.* and the effect of drought conditions on the vegetative and reproductive stage'.

A student report by Mr Zenani is included in this annual report. Some of the result highlights for deliverable 5 are presented in the accompanying figure.

Deliverable 6 (*Cannabis sativa* water-use estimates based on pot- and field-based trials)

This deliverable will be a report on the water-use estimates obtained from the pot- and field-based trials. This report provides the background required for the modelling activities. Due date for deliverable is 30 November 2023.

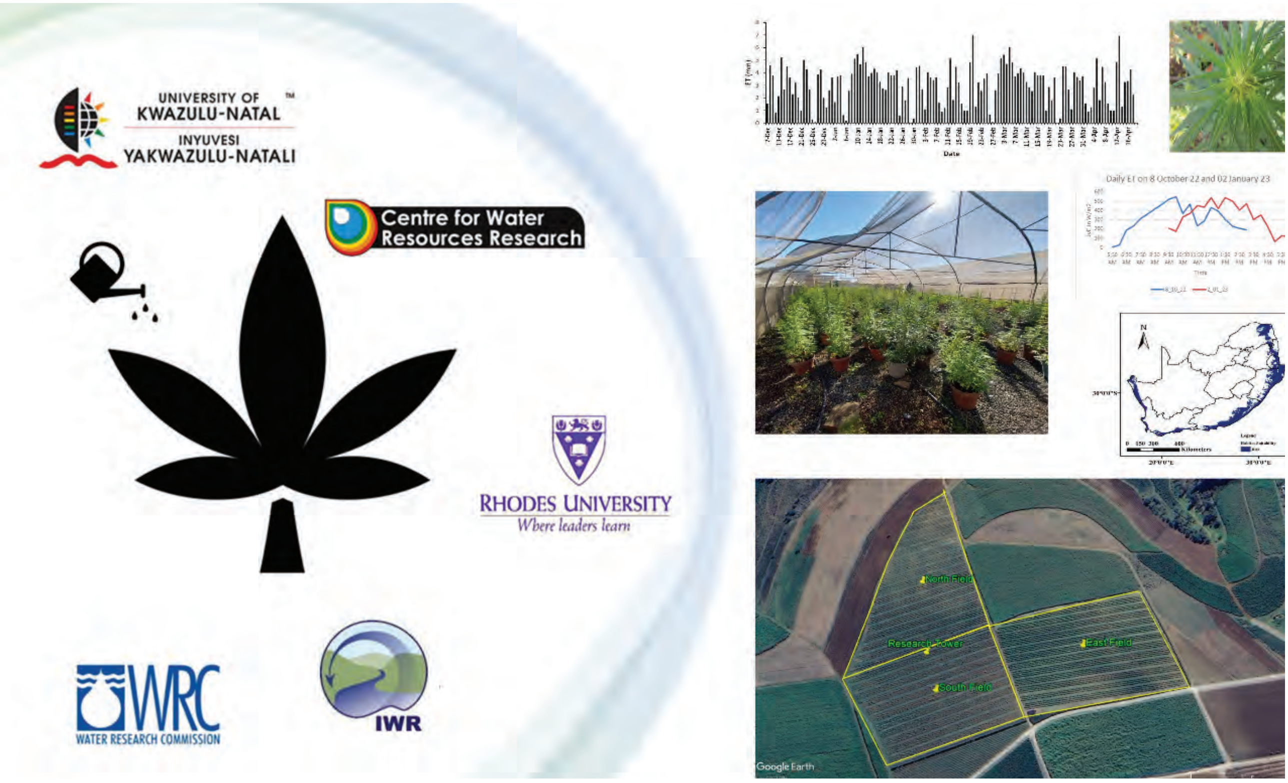
A pilot study into a new research direction is being planned for the *Cannabis* growing season of November 2023 to March 2024 in the Eastern Cape. We will be collaborating with two new partners: Dr Garth Cambray of Makana Meadery, who is interested in connecting resources with sustainable development, and technology transfer opportunities through value of cultural capital, land, biodiversity resources. Dr Cambray is producing clones for this study. The second new partner is Prof. Joanna Dames, mycologist in the Department Biochemistry, Microbiology and Biotechnology at Rhodes University. She is preparing mycorrhizal inoculum, whose effect on *Cannabis* growth will be tested as a treatment in the upcoming experiment at Firglen Farm. The aim of the study is to quantify the yield (bud mass at harvest) and growth variables (height, width) relative to water availability.

Dr Cambray is also assisting with planning stakeholder engagement workshops through his connection with Eastern Cape chiefs in rural areas who are interested in growing *Cannabis*. The workshops will share the project results and gather information on relevance of project results and barriers to *Cannabis* growth.

Outputs and impact

Mr Kamva Zenani (Rhodes University MSc student) submitted his thesis for review in August 2023.

Two deliverable reports to funder WRC (5 and 6).



Partners and some results from the research of the three MSc students under the Cannabis project.

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

C.F. Nnadozie, C. Knox, O.N. Odume, and R. Tandlich
Collaborators:
April 2019– March 2023

Sponsor: Water Research Commission

Locally, rivers are affected by fecal pollution from livestock practices, outdated wastewater treatment plants, and agricultural activities. Surface water is consistently implicated in the transmission of bacteria to humans, including antibiotic-resistant strains. Direct contact with and consumption of fecally contaminated water are principal risk factors for Campylobacteriosis, a disease caused by *Campylobacter* spp. and the leading cause of diarrhoea worldwide. South Africa, being a water-scarce country, relies heavily on surface water resources for irrigation, domestic, recreational, and industrial purposes. The purpose of this study is to investigate the occurrence and human health risks of *Campylobacter* species in the Bloukrans River in the Eastern Cape, South Africa, and to analyse *Campylobacter* antibiotic resistance in the country. The study employed both culture-dependent and culture-independent (molecular-based) approaches as well as desktop analysis. The results indicate that the high occurrence of *Campylobacter* and the presence of antibiotic resistance genes in the river system pose a significant public health concern, with livestock grazing around the Bloukrans River identified as a major contributor to bacterial pollution.

Livestock grazing at the Bloukrans River, Eastern Cape, South Africa, a major contributor to bacterial pollution and a potential source of Campylobacter species.

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

C.F. Nnadozie

July 2021– June 2024

Sponsor: European & Developing Countries Clinical Trials Partnership (EDCTP) supported by the European Union

South Africa is marked by significant wealth disparities and high rates of poverty-related diseases such as HIV/AIDS, tuberculosis, and diarrhoea. In urban centres, overloaded wastewater treatment facilities discharge inadequately treated effluents into rivers. This situation puts the urban poor, including children, mothers, and adolescents who use rivers for recreation, spiritual activities, and fishing, at high risk for Campylobacteriosis. Given the connection between diarrhoea, poverty, and environmental quality, an integrated, systemic approach to address the multiple risks associated with Campylobacteriosis is crucial. This study uses Next Generation Sequencing, Machine Learning, microbial ecology, and risk mapping to explore the links between urban poverty, service delivery failures, and Campylobacteriosis. Preliminary results underscore the need for continuous monitoring to manage childhood diarrhoea effectively.

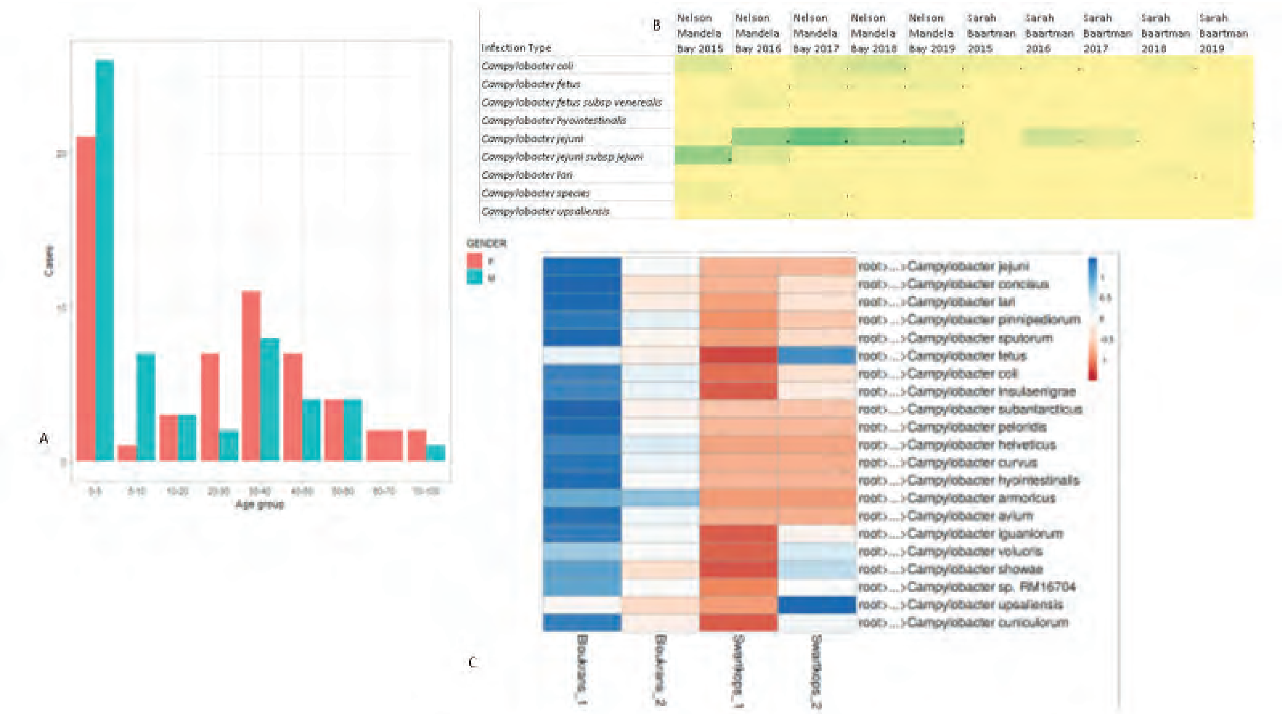


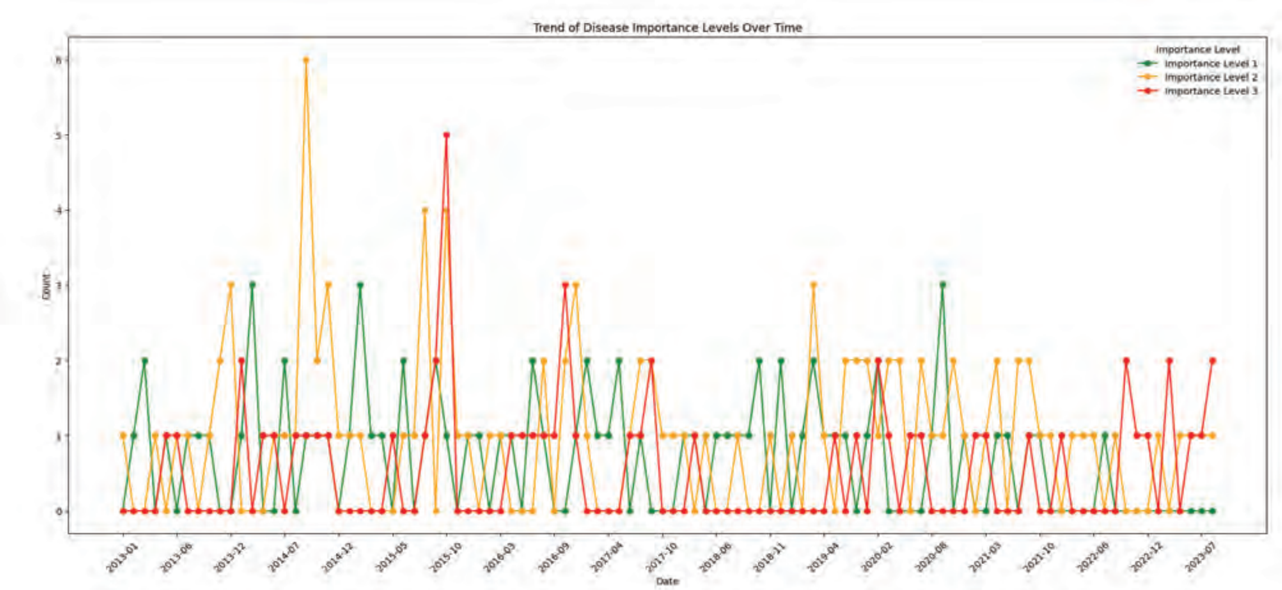
Figure (A) Distribution of Campylobacter cases by gender in each age group for both Nelson Mandela Bay Municipality and Sarah Baartman District Municipality; (B) Culture-confirmed human Campylobacter infections in Nelson Mandela Bay and Sarah Baartman District municipalities based on specimens submitted to the National Health Laboratory Service in Port Elizabeth, Eastern Cape, South Africa each year for Campylobacter spp infections, 2015–2019 ; (C) Heat map showing presence/absence of Campylobacter species in Bloukrans and Swartkops Rivers

An integrated approach to timely detection and prevention of waterborne zoonoses outbreak in selected municipalities of Eastern Cape, South Africa

C.F. Nnadozie, O.N. Odume, F. Akamagwuna, S.M. Mazibuko and N. Mgaba
Collaborators: Dr V. Msimang (South African National Health Laboratory Services (NHLS) and National Institute For Communicable Diseases (NICD))
April 2023 – March 2026

Sponsor: Water Research Commission

As climate change progresses, the incidence of waterborne zoonotic outbreaks is expected to increase, worsening the situation for both recreational, and private or communal drinking water sources, which are known to be sources of such outbreaks and sporadic diseases. This project aims to develop an integrated surveillance system by combining environmental, community (human), and animal surveillance data to detect emerging infectious disease threats and prevent waterborne zoonoses outbreaks. Preliminary data, particularly from 2022 onwards, reveal a significant rise in zoonotic disease animal cases in Eastern Cape, underscoring the need for enhanced surveillance, rapid response measures, and targeted public health interventions to manage these emerging challenges effectively.



Trend in the levels of importance of waterborne bacterial zoonoses over time based on veterinary clinic data in the Eastern Cape. The x-axis represents time, with each point corresponding to a month, from 2013 to December 2023. The y-axis shows the count of occurrences for each level of importance, where the levels are defined as: 1 = one case, 2 = more than one case but less than ten, and 3 = more than ten cases reported. Each line represents a different level of importance (1, 2, or 3), illustrating how the frequency of these levels changes over time.

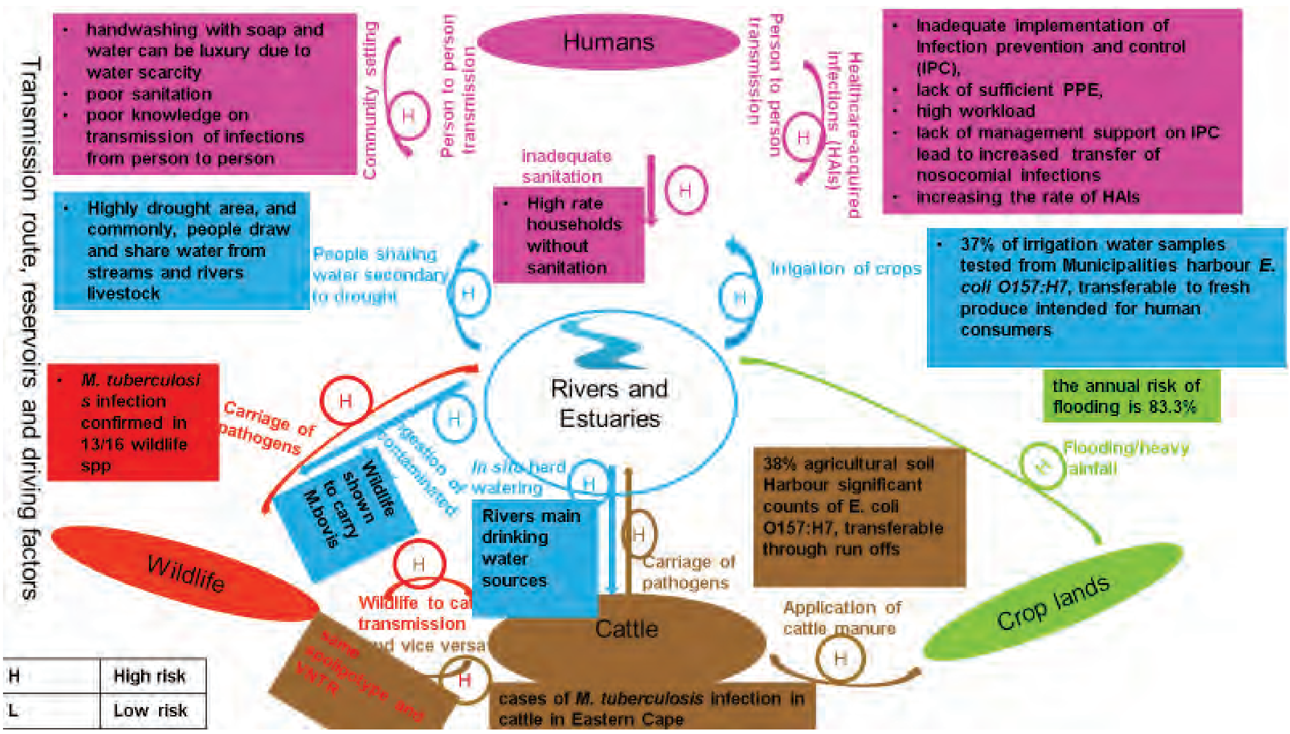
Applying an integrated environment, animal and human disease surveillance for early detection and prevention of bacterial zoonoses from a selected source water in the Eastern Cape

C.F. Nnadozie

April 2023 – April 2026

Sponsor: South African Medical Research Council

The project's goal is to analyse specimens from local humans and animals to identify zoonotic pathogens that can be transmitted through water. The analysis seeks to pinpoint the primary sources of these pathogens in river environments and to investigate the exposure pathways that enable the spread of bacterial diseases between animals and humans. Early results from the analysis reveal that accidental ingestion of contaminated water is a significant factor in the transmission of the studied pathogens. By evaluating the normalised and summed weights for each transmission pathway, the study identifies those pathways that are most critical for the spread of zoonotic diseases. The pathogens *Campylobacter* spp. and *Vibrio* spp. are targeted in this study owing to their established local presence in selected source waters in Eastern Cape. Their inclusion was based on a subjective assessment of existing information.



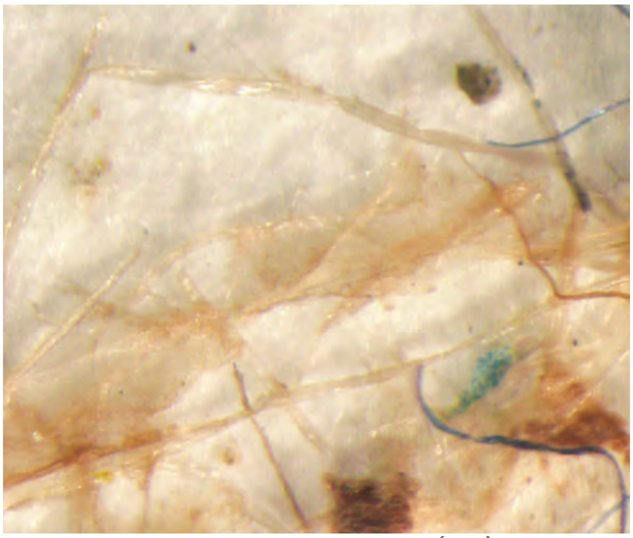
Transmission route, reservoirs and driving factors of surface waterborne bacterial zoonoses

Assessing the impact of different pollution sources on the type of microplastics, associated microbial communities, anti-microbial resistance and transport of microplastics in selected urban rivers in South Africa.

C.F. Nnadozie
Collaborators: I.D. Amoah, R. Indhur, N. Malambule and S. Kumari (Institute for Water and Wastewater Technology, Durban University of Technology, Durban, South Africa)
April 2022 – March 2025

Sponsor: Water Research Commission

The goal of this project is to use an interdisciplinary approach to better understand the risks associated with microplastic (MP) emissions into aquatic ecosystems. The study examines how MPs can act as carriers for bacterial and viral pathogens, as well as for antibiotic-resistant genes, in both wastewater and freshwater environments. This approach integrates chemical analysis, microbiological assessments, and molecular techniques to investigate these issues. The Umgeni River in KwaZulu-Natal and the Swartkops River in the Eastern Cape have been selected for this research. Initial results from the microplastic sampling indicate that fibres are the most common type of microplastic found in both rivers. The patterns of land use and activities within the catchments are also identified as factors that may influence the presence of microplastics.



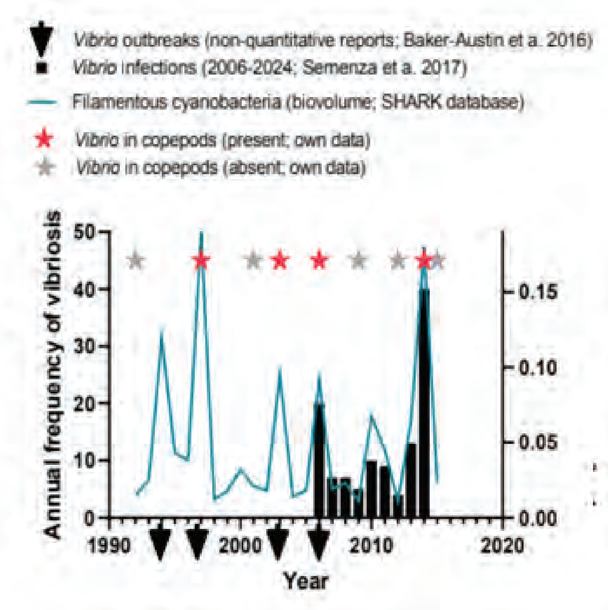
A photograph of a type of microplastic (film) detected in Swartkops River, Eastern Cape South Africa

Cyanobacteria - the missing link in vibriosis spread

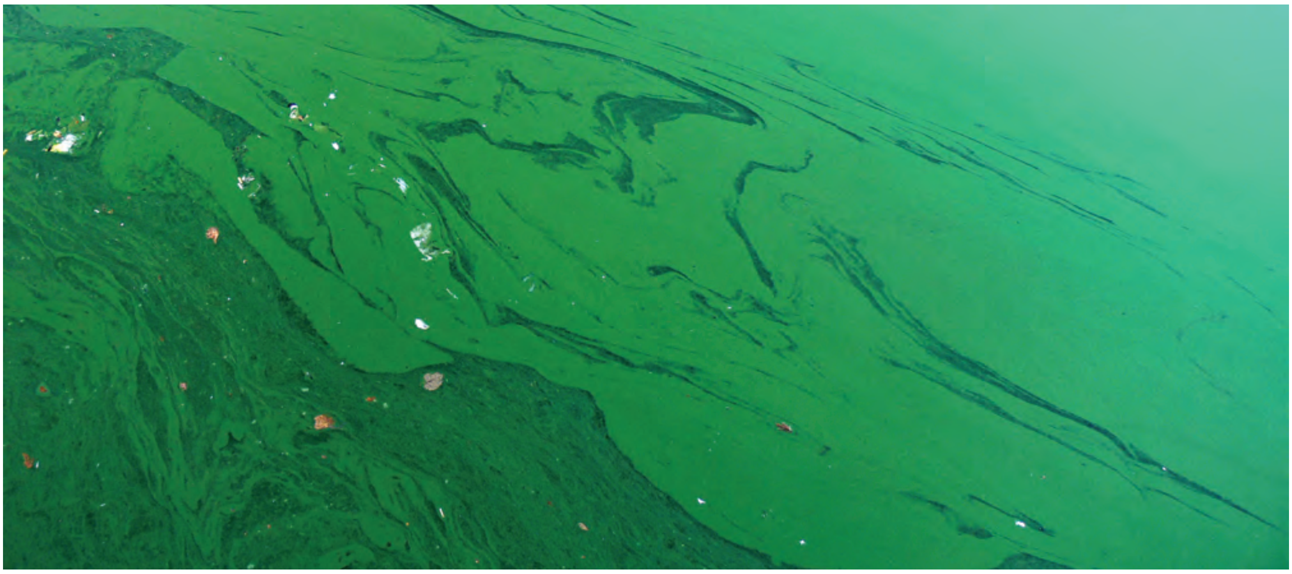
O.N. Odume, C.F. Nnadozie, F.C. Akamagwuna,
Collaborators: R. Amer (City of Scientific Research and Technological Applications SRTA-City), G. Bwire (Makerere University), R. El Shehawy (Stockholm Universitet), H. Pienaar (Council for Scientific and Industrial Research Natural Resources) and E. Vellemu (Center for Agricultural Transformation, Malawi).
January 2022 – December 2024

Sponsor: Swedish Research Council

Climate change is contributing to the spread of vibriosis, a disease caused by *Vibrio* bacteria, by creating more favourable conditions for *Vibrio* growth and affecting ecological components like bloom-forming cyanobacteria, which facilitate *Vibrio* persistence in ecological reservoirs. The aim of this project is to investigate how climate change influences vibriosis by analysing *Vibrio* bacteria in aquatic ecosystems, exploring their ecological reservoirs, assessing the impact of environmental factors, natural substrates and plastic pollution, and using food web components and cyanotoxins to understand trophic relationships and bacterial spread.



In the Baltic Sea, during the years with elevated vibriosis frequency, we observed very high cyanobacteria blooms, which coincided with occurrence of Vibrio in the microbiome of Eurytemora affinis (Copepoda). All data originated from the northern Baltic proper, where a strong increase in environmental suitability for Vibrio has recently been established. Low vibriosis frequency in human population and no commensal vibrios were found during the low-bloom years.



Governance and institutional arrangements for accelerating equity in the water-land-agricultural nexus: A case study of resource-poor farmers in smallholder irrigation schemes in the Lower Sundays River and Great Fish River catchments.

O.N. Odume, F. Materechera-Mitochi, S. Ngilana

April 2023–November 2025

Sponsor: WRC

Background

The contribution of resource-poor farmers to the South African agricultural economy is continually adversely impacted by a host of factors that limit their potential to participate positively in agricultural development. There have been numerous government policies and interventions targeted at supporting emerging farmers in order to increase their capacity to contribute positively to the agricultural economy against the backdrop of historical inequities created by the apartheid system. The issue of water allocation reform (WAR) in irrigation schemes as implemented by the Department of Water and Sanitation (DWS) is an example of an attempt to effect change in the way in which water for productive purposes is distributed among South African farmers. One other governance arrangement and support measure attempted by the South African government is that of joint ventures (JVs), defined as a strategic partnership in which the government facilitates the pairing of an emerging farmer with an established commercial farmer for capital and economic purposes, achieved through the medium of WAR.

Within the context of JVs at farm scale, WARs have been viewed as tools to effectively achieve the equity imperative contained within the National Water Act (NWA) No. 36 of 1998. Empirical evidence, however, reveals that most of the irrigation schemes currently documented in the country are dysfunctional and the joint venture partnerships have not yielded the desired outcomes, so impeding the potential of emerging farmers to contribute to the agricultural economy of South Africa. Research also reveals that WAR and policy have not brought about the expected or intended socio-economic and livelihood benefits to resource-poor/emerging farmers.

It is within this context that the proposed research is positioned. The research aims to investigate governance and institutional measures necessary to support emerging/resource-poor farmers at the farm scale, drawing on best international practices. It is argued that in order to achieve success, an exploration is necessary of the governance and institutional measures attuned to local realities and farmers' perceptions and of the power dynamics at the farm scale with political influence, polity and policy agendas across scales of government within the water-land-agriculture nexus. The study uses the Lower Sundays River and Great Fish River catchments as case studies to co-explore social, institutional and governance innovations to accelerate equity goals at the farm scale alongside farmers' perceptions of WAR and JVs and the institutional and governance challenges that may impede success.

There is a disjuncture between the expectations placed on emerging farmers to put allocated water to productive use for farming enterprise and the lack of institutional arrangements, mandate and governance processes to provide them with the resources needed to meet these expectations. This project aims to contribute to the knowledge gap regarding the misalignment between governance and institutional arrangements on the one hand, and equity imperatives on the other.

Project aims

The project is informed by the following specific aims:

1. To examine the disparity between relevant policy intents and implementation of equity goals via joint ventures within the context of WAR in the Lower Sundays River and Great Fish River Catchments.
2. To analyse the enablers and/or barriers to the benefits intended for emerging farmers via joint ventures. Such benefits may include social, economic, livelihood and technical know-how benefits.
3. To analyse the governance dimensions, and the suitability of joint ventures for realising equity, efficiency, and sustainability imperatives in the context of water allocation reforms within the Lower Sundays River and Great Fish River Catchments.
4. To explore governance and institutional measures/arrangements/systems, including

polycentricity, necessary to support emerging/resource-poor farmers at the farm scale to achieve the imperative of equity.

Project approach and methodology

The study employs a mixed methods approach and combines several data collection techniques to gain insights and synthesise knowledge in order to achieve its objectives. Primary and secondary data will be collected through document analysis/desktop study, workshops, in-depth interviews, and questionnaire development.

Project progress to date

The project, which officially started in April 2023, is ongoing. The initial stages of the project established relationships with the relevant actors in order to facilitate the co-creation of knowledge as envisioned by the project aim. The project research team undertook a series of initial site visits and workshops to introduce the project, familiarise themselves with the different actors and to obtain the necessary gatekeeper permissions to proceed with project activities.

The first site visit to the Lower Sundays River Catchment took place on 11 April 2023. Prof. Nelson Odume, Dr Fenji Materechera-Mitochi and Mr Simphiwe Ngilana travelled to the offices of the Lower Sundays River Water User Association (LSRWUA) in Kirkwood to attend a sitting of the Catchment Management Forum (CMF). The project team was invited to make a presentation as part of the programme of the CMF to introduce the project to stakeholders with interests in water use within the catchment. Stakeholders included representatives from the DWS, Local Farmers' Associations, the Water User Association and community interest groups such as the Sundays River Valley Collaborative (SRVC). Dr Materechera-Mitochi presented the project after which Prof. Odume facilitated a discussion addressing questions, concerns and points of clarification raised by the audience. The project was warmly welcomed and the post-presentation discussion raised issues of concern that the project team ought to take into consideration. To date the project team has attended all other scheduled CMF meetings as a recognised stakeholder (25 May 2023, 28 June 2023). Before the adjournment of the CMF, the project team embarked on a guided tour of the study area accompanied by CMF members. The tour included a stop at the Sundays River Canal which is supplied by the Gariep Dam and is an example of a JV in the Sundays River Valley, namely the farmland area designated for the *Ikamva Lethu* – Xhosa for *Our Future* project.

The first site visit to the Great Fish River (Tyhefu) Catchment took place on 12 April 2023 at the office of the Ndlambe tribal authority where Chief Makinana resides. A meeting was held between the chief, tribal council members, the project team (Prof. Odume, Dr Materechera-Mitochi and Mr Ngilana), stakeholders from the Department of Rural Development, Agriculture and Land Reform (DRDLR), extension workers, and representatives from the National Development Agency. All members at the meeting had varied interests in water-related issues within the catchment area. A presentation of the current project by the project team was included in the meeting agenda. Dr Materechera-Mitochi delivered the presentation with the aid of Mr Ngilana who interpreted into the local Xhosa language. The presentation was followed by a facilitated discussion in which members of the meeting were given the opportunity to give their feedback on the presentation and express their opinions. Chief Makinana welcomed the project team and provided his verbal authorisation for the study to be conducted in the area. All necessary gatekeeper permissions were obtained from the relevant authorities in both catchments. Ethical clearance was obtained from the Rhodes University Human Research Ethics Committee (RU-HREC) on 22 August 2023 (Ethics approval number: 2023-7264-7948).

Data collection commenced on 9 October 2023 in the Sundays River Valley with in-depth interviews with farmers in JVs and key informant interviews with relevant actors in the citrus production value chain in the area.

Equity dimensions of the Nelson Mandela Bay water crisis and the implementing context as enabler or barrier for upatake of translatable lessons from the Cape Town water crisis

O.N. Odume, C. Murata, K. Mgaba, J. Alexander, T. Masilela, V. Mlonzi, C. Matomane, N. Mqoqi, S. Kinzela, S. Mjuleni

Collaborators: O. Barreteau (Montpellier University), E. Mack (Michigan State University)

April 2023–March 2025

Sponsor: Water Research Commission (WRC)

This project considers the multiple dimensions of water access and equity when it comes to water security in Nelson Mandela Bay (NMB). Considering the very serious drought the Metro experienced, the project also seeks to understand if any lessons learnt from the Cape Town water crisis might be applicable to the Nelson Mandela Bay context, as both cities faced Day Zero scenarios.

Climate change means that prolonged droughts are becoming an increasingly common feature in South Africa and are a major cause for concern across municipalities, particularly those that do not have ready access to abundant water sources. The Nelson Mandela Bay Metropolitan area was in the grip of a severe drought between 2017 and 2023. While time and effort were spent diversifying water sources, the extensive drought, failing water infrastructure and ongoing municipal dysfunction in the Metro meant that residents were severely affected, and water security remains a central concern for all.

Data is being collected for the project from a variety of sources: quantitative surveys to qualitative interviews; participatory research tools such as a water equity game that has been especially designed around the NMB ecosystem; focus group discussions, and participatory mapping. Fieldwork takes place across a variety of different interest groups, spatially and demographically mapped across the Metro to ensure adequate representation. Research for the project is designed to have an iterative participatory backbone, with participatory engagement via a Living Lab – a social engagement platform that collaboratively explores the various themes which emerge from the research. Participants from the Living Lab have also become involved in the data-collection process and form a vital part of grounding the project at a grassroots level, as well as incorporating engagement with qualified experts actively responsible for water provision and services in the Metro. The study is ongoing, with further research planned to investigate the governance and implementation environment that continues to affect water security in the Metro, and potential ways in which this might be supported and improved.

Water quality remains a concern after several health scares. Municipal water is regularly monitored, but freshwater in catchments is severely impacted. People fishing along the Swartkops River report that fish caught in particular areas along the river are inedible, as they are heavily affected by pollution from heavy metal contaminants, untreated sewage, and industrial effluent which flows into the river.

Over and above the devastating effects of the eight-year drought, service delivery to Metro residents, businesses and social service institutions is increasingly hampered by long-term political instability and municipal dysfunction. The systemic problems with governance and municipal mismanagement in the Metro contribute towards water insecurity that is felt most strongly by vulnerable groups.

Those who need access to water and sanitation services the most currently hold the shortest end of the stick, especially when it comes to visible service delivery and relief services, for example, water trucks, and fixing water and sewage leaks. Lower income areas and informal settlements have a greater need for alternative water provision, and the limited supply means that water becomes a scarce resource that can become a source of conflict. The limited relief water available in low-income, high-density areas contributes to social unrest and has a knock-on effect in relation to equity.

Other factors contributing to water insecurity are loadshedding and high levels of theft and vandalism, especially targeted theft of copper pipes and fittings – a problem which is evident across South Africa. The municipality also reports an alarming rise in non-payment of tariffs, for example by landlords or those who inherit municipal debt, which the team found was prevalent in many low-income RDP areas. Migration to a Metro with low employment prospects means the municipality is faced with a rise in indigent households who cannot afford to pay for water.

What is clear from interventions that were put into place (e.g., raised tariffs and water cuts) to deal with the water crisis is that there was an extensive focus on the technical dimensions of responding to the drought, with less attention given to how these measures could potentially impact different societal constituencies, and their equity implications. One of the biggest findings so far has been to realise the multiple ways in which water can be a tool for both social unrest and social cohesion. In some of the more affluent areas, water provision has become one of the ways in which people can give back to their community, for example, by sharing water from rainwater tanks or private boreholes. Looking at the socio-cultural dimensions of water security allows us to see just how powerful a tool water can be for social cohesion and wellbeing as well as ecosystem health and sustainability.

Participants from the Living Lab playing the water equity game designed around various forces impacting upon water security in the Metro

Participants consider various scenarios that can improve or detract from water security across different user groups

Water leaks are a frequent concern across the Metro

Fisherman on the banks of the Swartkops Estuary

Residents collecting water from a tanker providing emergency water services

Modelling uncertainty and reliability for water resource assessment in South Africa (MURRA)

J. Glenday, J.L. Tanner and D. Gwapedza
Collaborators: A. Rebelo (ARC, South Africa), P. Holden (UCT ACDI, South Africa), P. Metho (Zutari, South Africa), S. Gokool (UKZN CWRR, South Africa), F. Jumbi (SAEON, South Africa)
April 2022–March 2024

Sponsor: Water Research Commission

Project background

This project comprised several engagement activities to develop a better shared understanding of uncertainty in hydrological modelling and ways to address it. Hydrological modelling has become central to water resources management and catchment management in South Africa. With ever-growing pressure on the nation's water supply systems, basing decisions on reliable estimates of surface and groundwater resource availability is critical. In recent decades, South Africa's meteorological and hydrological monitoring infrastructure has declined severely. The sector relies on models to fill in gaps in monitoring and to forecast the future, predicting streamflow and groundwater under future climates, land uses, and management practices. As reliance on modelling grows, so too should attention to model uncertainty: quantifying it, finding practical ways to reduce it, and accounting for it in decision making.

Despite a growing body of global and local research on uncertainties in hydrological modelling, it remains common practice in applied and operational contexts for model outputs to be presented as single values or timeseries, without indicating the uncertainty inherent in the prediction. Without any quantitative indication of uncertainty around a predicted value, decision makers are ill-equipped to consider risks when using these values to make their decisions. This can lead to inappropriate management with negative consequences.

To address issues around insufficient consideration of hydrological modelling uncertainty, this project had the following aims and objectives:

Aims

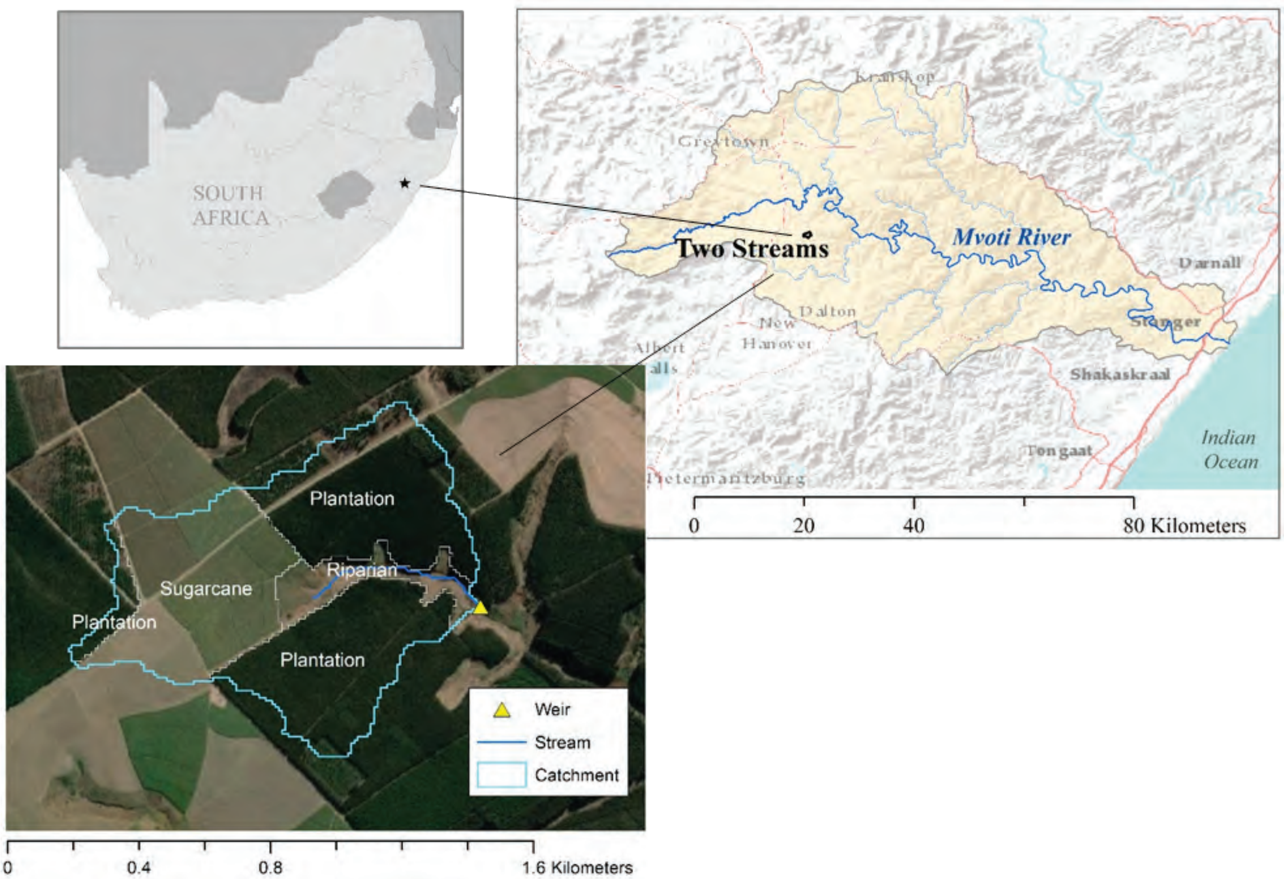
- To improve shared understanding of model structural uncertainty, and the role of modeller decision making, and the potential scale of impact across the hydrological modelling community;
- To empower the community to identify practical strategies for assessing, communicating, and ideally reducing modelling uncertainty.

Objectives

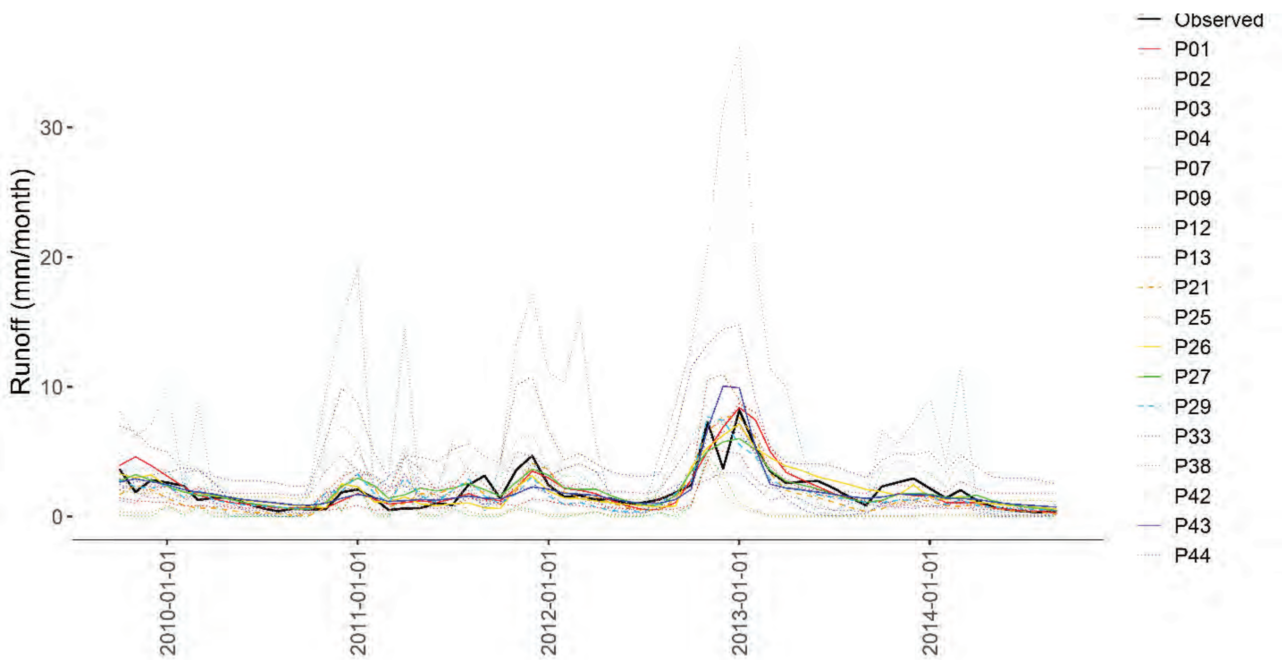
- Design and host an open 'model-a-thon' activity in which participants from across the water sector model the same catchment area, given the same input and calibration data, and apply the model to the same alternative scenario.
- Assess and discuss the diversity of modelling approaches, structures, and output predictions in the 'model-a-thon' activity as a means of collective scoping of the issue of structural uncertainty.
- Host synthesis engagements to discuss the implications of the findings around modelling uncertainty for future water resources studies and initiate visioning of how these studies can be done in a way that accounts for and, where feasible, aims to reduce uncertainty.
- Synthesise the engagement outcomes into a policy brief.
- Promote online resources that can build capacity across the South African hydrological modelling community, specifically a 'wiki' website about modelling tool options and capabilities (https://hydromodel-sa-wiki.saeon.ac.za/) and the online question-and-answer platform (Stack Exchange) to facilitate information sharing.

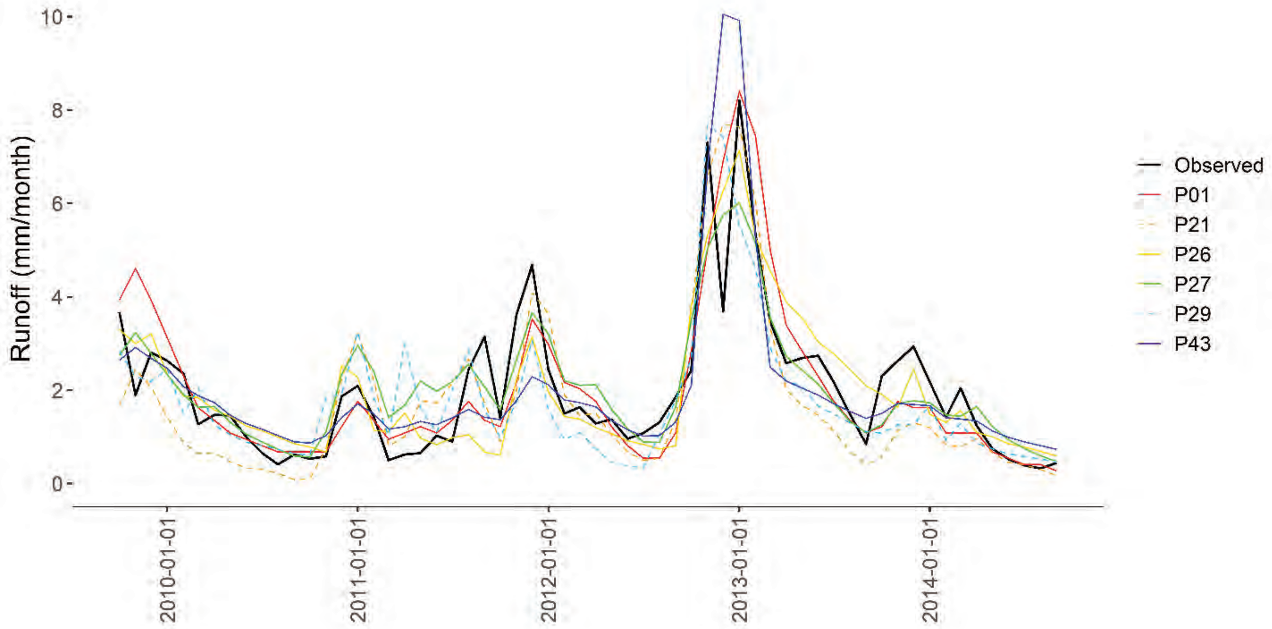
Progress

The project team successfully developed and hosted South Africa's first catchment hydrology model-a-thon in October-December 2022. The activity was launched at the South African Hydrological Society (SAHS) inaugural conference. Volunteering participants were asked to model the Two Streams catchment on the upper Mvoti River, under both baseline land cover, with sugar cane, mature wattle plantation, and riparian vegetation; and an alternative cover scenario, in which the wattle plantation had been cleared and replaced with sugar cane. All participants used the same input data and information and streamflow dataset, against which to calibrate their baseline model. However, they were free to decide what modelling software tool to use, how to construct and parameterize their model, and how to approach calibrating it. A total of 38 modellers signed up to participate, and 19 models were submitted by the final (extended) cut-off date. Participants ranged in experience level, from post-graduate students to modelling experts in consulting and academia, and in the modelling tools they used, with models being built with five different software tools (WRSM-Pitman, SPATSIM-Pitman, ACRU, SWAT, and MIKE-SHE).

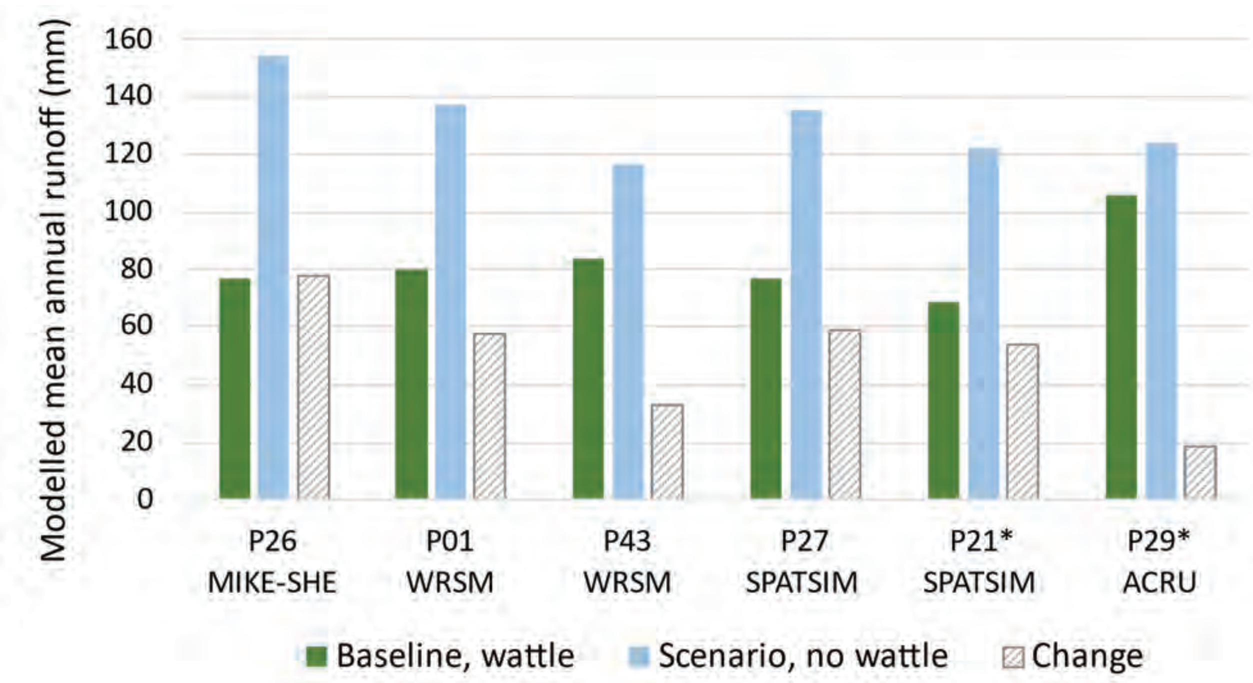


Two Stream catchment area, upper Mvoti River, the case study used for the model-a-thon activity.





Monthly observed and modelled hydrographs for the Two Streams catchment for all models (top) and higher performance models (bottom) for the calibration period, 2009/10/01–2014/09/30



Modelled mean annual runoff with and without the wattle plantation for the period (2003–10 to 2014–09) predicted by the higher performance models

The project team analysed the modelling submissions and the results were presented to all those who signed up to the activity in an online discussion session held in March 2023. The baseline models were assessed in terms of how well they were able to re-create the observed streamflow, as well as the degree to which their predictions of evapotranspiration, subsurface storage, and surface vs. subsurface flow corresponded to observational data available for the catchment. The predicted change in streamflow due to the removal of the wattle plantation was also assessed across all submissions. Recognition was given for the best performing models and a prize was awarded for the best performing model from a student. This was won by Sinethemba Xoxo, a doctoral student at Rhodes University IWR. The best performing models came from a variety of modelling tools and had a variety of structures, and not all were built by highly experienced modellers; they were generally those for which an automated calibration tool was used and on which the modeller spent more time.

The results illustrated the high degree of uncertainty that can be present in model predictions of change, even when there is observed streamflow data available to assess and calibrate a baseline model. Across the four models with the best baseline streamflow performance, the predicted increase in mean annual streamflow due to removing the wattle plantation ranged from 39% to 101%. One can assume uncertainties would be far higher for cases where models are applied to predict changes for ungauged catchments. If models were further assessed using the additional hydrological data available for Two Streams, a well-researched catchment, uncertainty could be reduced. It was found that one of the models with good streamflow performance was greatly over-estimating how much surface flow there was and underestimating subsurface flow. If this model was excluded, the range of change predictions from accepted models dropped notably to be 72% to 101%.

This participatory modelling activity was followed in July 2023 by facilitated online discussion sessions with modellers in consulting and academia, and users of models and model outputs in operational and decision-making contexts within the Department of Water and Sanitation (DWS). The goal of these discussions was to understand how the issue of modelling uncertainty is perceived by different stakeholders and to identify what would enable greater consideration of uncertainty in practical contexts. The project team has synthesised the outputs of these conversations into a policy brief on uncertainty in hydrological modelling. The brief highlights the problem of ignoring modelling uncertainty in decision-making and management, given that it is often substantial. It proposes both programmatic recommendations, such as capacity building and standardisation of uncertainty analyses protocols for different instances of risk and data availability, as well as modelling process recommendations, such as routine parameter sensitivity analyses and the use of multi-model ensembles. This brief is currently under review by the participants of the discussion sessions. Once finalised it will be made available online and publicised via the WRC and SAHS.

Revision of the 1996 South African water quality guidelines: development of risk-based approach using aquatic ecosystems responses

Prof. O.N. Odume, Dr N. Griffin, Dr P. Mensah, Mr D. Forsyth
Collaborators: Dr L. Ncube, Ms E. van Niekerk
April 2020–December 2023

Sponsor: Water Research Commission

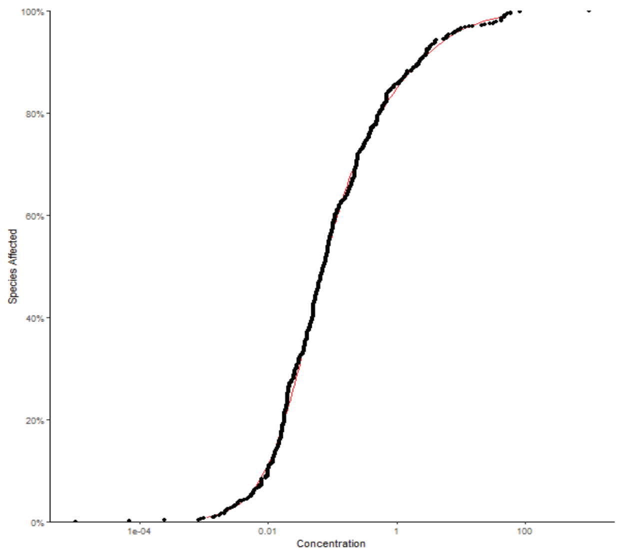
This research project focuses on the revision of the 1996 South African water quality guidelines for freshwater ecosystems, with a view to developing risk-based guidelines operationalised through a software-based decision support system. The final system will have spatially specific guidelines for a 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 realization that the 1996 water quality guidelines have limitations in several important areas: i) non-alignment with approaches to water resource protection; ii) not being sufficiently risk-based; iii) lacking internal coherence between guidelines for different users; iv) not reflecting the full range of critical water quality variables such as persistent organic pollutants (POPs), pesticides and endocrine disrupting compounds (EDCs), 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.

The project team attended a planning workshop in Maputo where considerable progress was made in the design of three tiers. Tier 1 is conservative and guided by multitaxon toxicological responses; Tier 2 is site-specific and modified to reflect local water quality, and Tier 3 was being refined.

The software tool for guideline derivation has been developed and is currently being refined. Using a database of toxicological responses, Tier 1 guidelines simply produce ecological category boundary values for 25 inorganic, 45 organic and 26 pharmaceutical compounds. Tier 2 guidelines produce locally appropriate (at ecosystem Level 2 scale) risk-based guidelines, using either water quality data or macroinvertebrate data to generate an estimate of risk. Tier 3 guidelines are issue-based, and allow a user to explore aspects of the risk scores generated by the other tiers.



Example of a species-sensitivity distribution curve used to derive Tier 1 water quality guidelines. The example plots the 50% lethality response of a range of taxa against the concentration of copper chloride causing that response.

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

Dr A.R. Slaughter, Dr N.J. Griffin, Ms S. Lazar, Prof. O.N. Odume, Dr F. Akamagwunu

March 2022 to March 2024

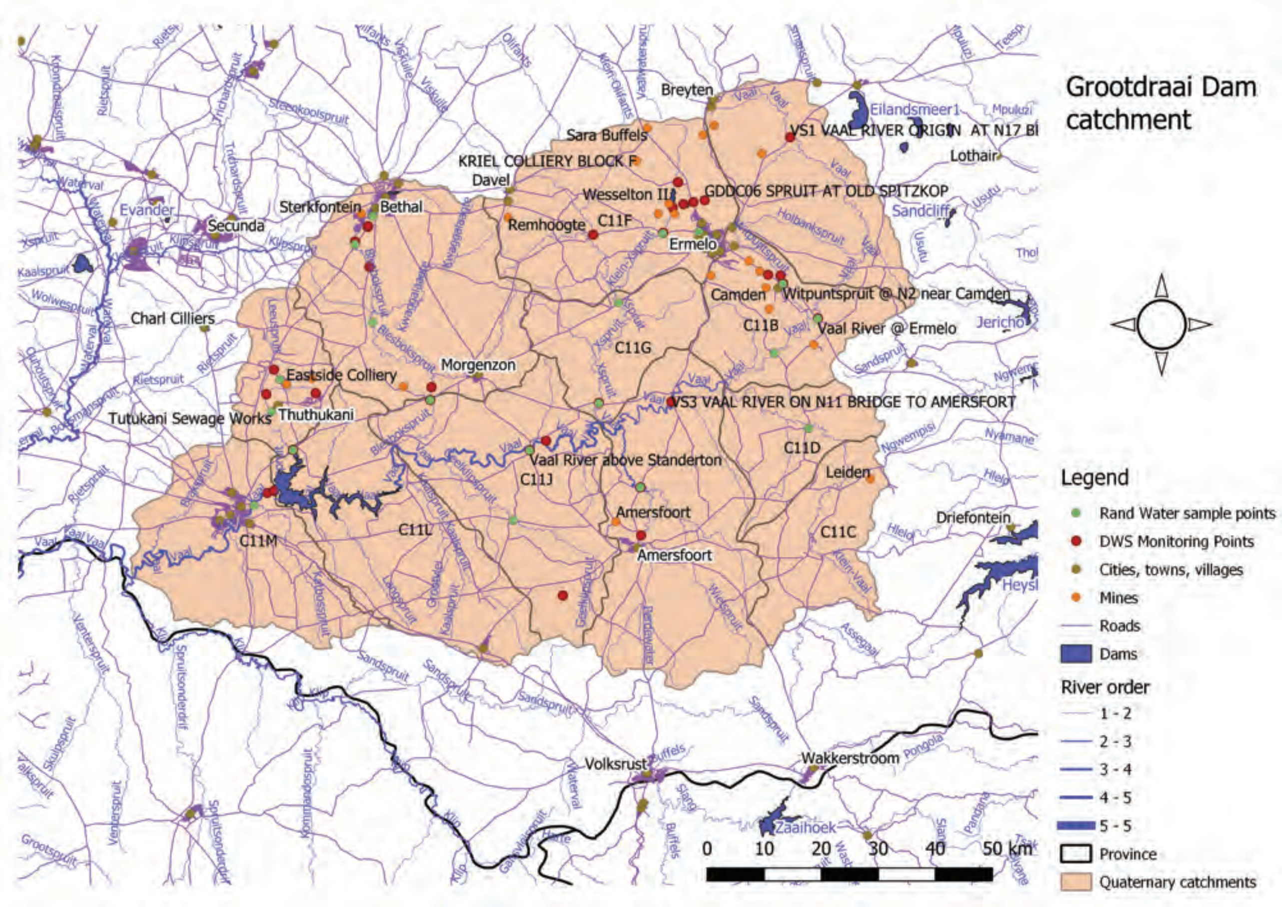
Sponsor: Water Research Commission

The deteriorating water quality in the Grootdraai Dam catchment above Standerton has serious economic, social, and ecological implications because of its strategic importance to South Africa's 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 owing to water scarcity within the catchment. The poor quality of the raw water makes it more costly to treat abstracted water to standard fit for industrial use, which then contributes to variable and operational costs of these industries, which, in the long term, can lead to job losses and put in jeopardy the viability of the operations of raw water-dependent industries in the catchment.

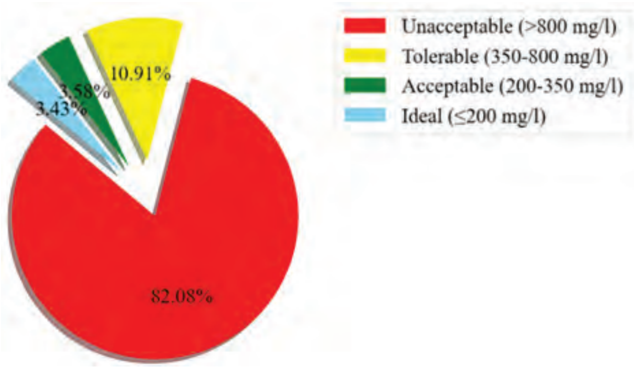
A water quality modelling approach was adopted to explore future water quality in the catchment and its response to various interventions. The project team are engaging stakeholders in the catchment and will continue in this regard. The DWS and Rand Water quality datasets for the catchment have been obtained.

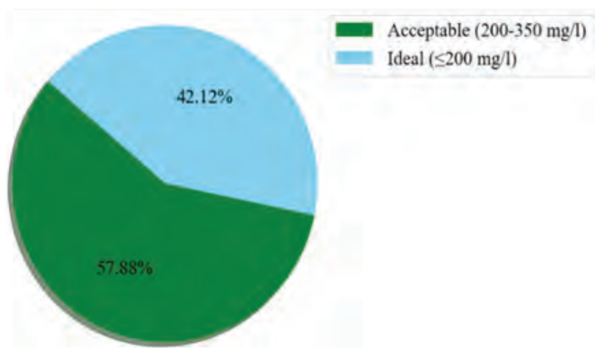
Python water resources (Pywr) was used to model yield from the catchment, calibrated against an extant water resources management plan (WRMP) yield model. This approach was taken to represent flows at a finer resolution than were contained in the WRMP yield model. To model water quality we had planned to use the Water Quality Systems Assessment Model (WQSAM), but problems with this approach led to re-coding WQSAM routines in Pywr to give Python water resources – Water Quality (Pywr-WQ), which was used for water quality modelling. A water quality model was set up in Pywr-WQ, and calibrated against DWS and Rand Water data to give the baseline condition. Models to medium- and long-term timeframes were run in Pywr-WQ where possible, and we used a multiple regression-based model when changes in land use were considered. Models were based on likely changes in the catchment as suggested by stakeholders in a workshop. Major consideration was given to the effect of climate change, expansion or reduction of coal mining in the catchment, changes in intensive agriculture, and changes in urban areas.

Climate change alone was found to have a limited impact on many water quality parameters, but certain salts and salinity increased relative to baseline with time. Combining this with a small increase in mining led to intolerable salinities in the future. Increases in cultivated land led to an increase in nitrogen nutrients, with the associated risk of algal blooms and/or ammonia toxicity. Increasing urban land in the catchment produced increased phosphate levels, which appear to be a function of increased wastewater leakage, a problem reported by stakeholders and the press. Looking at scenarios where a combination of several changes were modelled together revealed that management of the catchment can lead to a future where cleaner water can be available, even with increased demand for water. The modelled impact of mining is significant, and uncontrolled increases here are a threat to water in the catchment. However, should coal mining decrease (as is anticipated under the proposed Just Energy Transition process), future salinity threats to the catchment will be reduced.



Grootdraai Dam catchment overview, showing towns, roads, rivers, dams, and water quality monitoring points.





Grootdraai Dam salinity under baseline conditions on the left, and under modelled climate change, mine closure and 70% Secunda water demand increase on the left. Data modelled for the year 2099.

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

Dr A.R. Slaughter, Dr N.J. Griffin, Prof. O.N. Odume

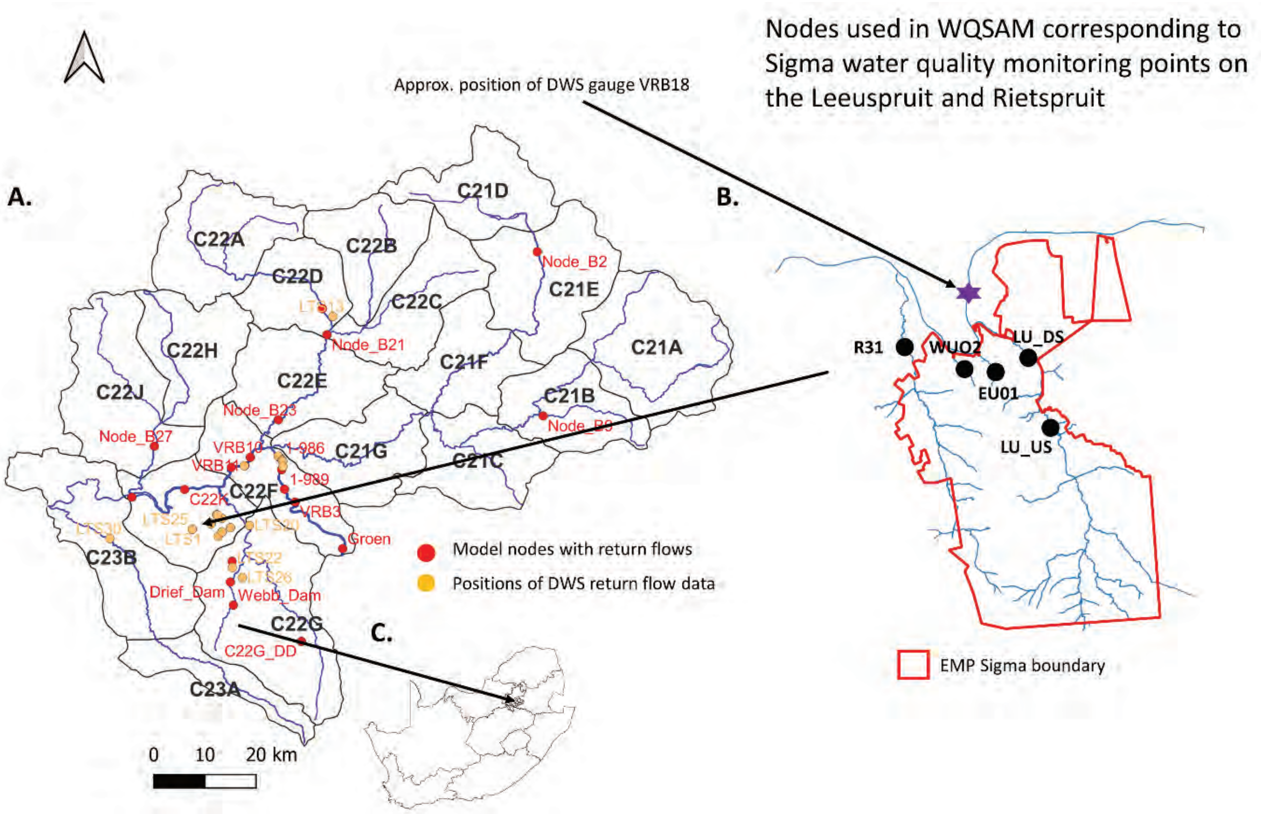
August 2022 to January 2023, and ongoing

Sponsor: Sasol Mining via Jones and Wagener

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 formally close the mine. As a part of this process, potential impacts and mine water management considerations for mine closure need attention. The best practice guidelines for this aspect of mine closure are the guidelines of the Department of Water and Sanitation that use source-pathway receptor and risk-based approaches to mine water management. Best Practice Guidelines (BPG) G4 impact prediction and BPG G5 water management aspects for mine closure outline requirements with which Sasol will have to comply.

Closure of the Sigma Colliery requires that water quality impacts on Vaal River Water are curtailed. Although the Leeuspruit carries water with salinity (mostly as sulphates) and nutrients (most notably as phosphate) to the Vaal, previous surveys have found no impact on 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.

As part of a larger specialist team, we modelled surface water quality in the Leeuspruit, the Rietspruit (south bank), two unnamed south bank tributaries and the Vaal River to simulate water quality in the region. This required modelling water quality in the Rietspruit (north bank) as this affects the Vaal River water quality in the Leeuspruit locality. The developed water quality model was then used to assess the impacts of mitigation through scenario analysis.



Map of the Sigma Colliery region within the Upper Vaal catchment.

Postdoctoral project reports

Bukho Gusha

Host supervisor: Dr Jane Tanner

Hub post-doc supporting research and stakeholder engagement activities conducted by the Ethiopia node. The node is working on resilient landscapes for enhanced water security and ecosystem service in the highlands of Blue Nile Basin, Ethiopia.

As part of the Strategic Adaptive Management workshop, I have been involved in several workshops in the node as well as being involved with the activities of the specific node. I have also been active in stakeholder engagement activities from Rwanda, Uganda and Tanzania.

I have assisted with postgraduate student supervision and been involved in both local and international grant applications. As part of the project activities, I have contributed to several peer-reviewed papers that have emerged from the project.

David Gwapedza

Host supervisor: Dr Jane Tanner

A postdoc in the IWR is unlike a typical postdoc; I have met postdocs from all over the world, and most are rather surprised at the work I do as an IWR postdoc. My experience in the IWR has been one of constant growth and transition. The institute lays sufficient scaffolding, and postdocs (and even postgraduate students) can climb as far as possible, as is evidenced in Director, Prof. Odume and Water CoE Director, Dr Jane Tanner. The two leaders were students in the IWR, transitioned to postdoc and now occupy leadership positions in the Institute. Other former students and postdocs of the IWR have left the Institute and occupy high-profile positions in organisations worldwide. So, I reiterate: a postdoc at the IWR offers unique professional growth. However, the IWR is a dynamic, fast-paced environment that requires individuals to adapt – hard work lies at the core of the institute's values.

As a postdoc in IWR from July 2021 to the present, I have worked on journal papers, grant proposal writing, research, project management, supervision, lecturing and community engagement.

Publication writing

I have authored five journal publications, two as first author and three as a co-author. The papers focus on hydrological and socio-hydrological aspects. I have several manuscripts in production, one under review and three due for submission in 2023. I am the main author of three of the four articles.

Grant proposal writing and project management

I have applied for several grants in the past two years; a few were painfully rejected but I highlight the successful ones. Apart from my key WRC-funded research project titled, "A stakeholder-driven process to develop a more equitable and sustainable water resource management plan", I have received two other grants as lead proposer. These are an NRF-funded mobility grant and an ARUA_U21 early career grant. I have also been part of two successful WRC grants focusing on uncertainty in hydrological modelling and rangeland management. I have been involved in researching and writing project deliverables for these projects.

Supervision and lecturing

I supervise Masters and Honours-level students. One Honours student has graduated, and another is completing their studies. A Master's student (Sakhi Mabohlo) is finalising his thesis writing. All the students have focused on hydrological modelling research. I lectured a Hydrology Honours course in 2022 in collaboration with Prof. Mantel and Dr Tanner.

Community engagement and volunteering

My participation in community engagement and voluntary work has taken various forms. For example, I am a reviewer for at least five international water research journals. As an external examiner for water resources modules at the University of Western Cape, I have also examined postgraduate students' theses. I support postgraduate students in the Institute and the university at large. I recently volunteered for the Ncedana mentorship programme at Rhodes University to support undergraduate students in coping with university demands.

The above highlights the range of work and responsibilities a postdoc at IWR engages in. Clearly, the work is broad and affords the postdoc opportunities to grow and develop various aspects of an academic career. Throughout, I have received support and mentorship from the Institute's staff. Constant encouragement from leadership fortifies one to take on responsibilities and challenges with courage. Being allowed to lead, with support, is a key strategy that the IWR uses to catapult emerging professionals to the height of their potential. Looking back, I gratefully reflect on the privilege of being a postdoc in the IWR over the past two years. This specific year has been packed with challenging but exciting work, among them two specific events:

ARUA SAM and Integration workshops

I attended a Strategic Adaptive Management (SAM) workshop in Rwanda and Uganda and then the Integration workshop in Uganda. These workshops were personally beneficial as I learned stakeholder engagement and facilitation techniques. I also formed networks and collaborated with researchers from other African countries.

Facilitating a group session at the Integration workshop in Uganda

Global-FRIEND Conference

The 9th FRIEND-Water Global Conference was held in the capital city of Senegal, Dakar, from the 25–30 September 2023. The conference was uniquely structured into presentations, training sessions and workshops, providing a variety of activities that kept the event exciting. Three training courses were provided on Ecohydrological Analysis of a territory, Hydrometry and Early Warning Systems. The conference provided opportunities to position the IWR for collaboration within UNESCO and regional IAHS programmes.

The 9th FRIEND-Water Global Conference 2023 group photo

Fenji Materechera-Mitochi

Host supervisor: Prof. Nelson Odume

I joined the IWR in February of 2023 as a new postdoctoral fellow. The year has been a fascinating and enjoyable transition into academic work after obtaining my PhD. My involvement in several projects has provided exposure to a broad spectrum of research foci, one of them being the Remediation of the Transboundary Ramotswa Aquifer between Botswana and South Africa, funded by the Southern African Development Community (SADC) and KfW Baken-gruppe of Germany. I worked on the stakeholder mapping component of this project.

I joined the project team for the ECWASA water infrastructure project for the Buffalo City and Kouga local municipalities funded by the German Federal Ministry of Education and Research. Together with the team, in February 2023, I assisted in organising a water workshop in East London that gathered stakeholders in the water sector from the metro.

I assisted in facilitating a word café as part of the workshop that engaged other collaborators from the Buffalo City Metropolitan Municipality (BCMM), representatives from the East London Industrial Development Zone, Amatola Water, the DWS and local engineers. The workshop was preceded by a one-day Springboard Conference at the East London International Convention Centre arranged by the IWR project team as the academic leads in South Africa in collaboration with our German partners. The conference objective was to formally disseminate information about the recommendations for the ECWASA project to leaders in the BCMM and facilitate information sharing on the key challenges and opportunities within the water sector in the Metro. The mayor and deputy mayor of the BCMM, together with the mayor of the Kouga municipality, attended and were given a platform to share successes and insights from those municipalities.

I joined the project team for the African Water Resource Mobility Network (AWaRMN) and have been actively involved in the network serving in an administrative capacity aiding in the overall administration aspects of the project that link five continental partners: South Africa, Uganda, Algeria, Nigeria and the Democratic Republic of Congo. I applied for academic mobility to one of our partner institutions as part of the project and was delighted to be accepted for a three-month stay at Makerere University in Uganda in 2024.

I was given the opportunity to lead a WRC project focused on governance and institutional arrangements to accelerate equity in the water-land-agricultural nexus in the Eastern Cape, an experience through which I gained a wealth of insight into issues surrounding water allocation reforms in South Africa. Supervising a PhD student as part of this project has provided a valuable introduction to the skills required for student supervision.

Outputs and impacts

- Community engagement through participation at all Catchment Management Forum (CMF) meetings held for the Lower Sundays River Catchment in 2023.
- Capacity development for post-graduate supervision and project administration.
- Two project reports/deliverables for WRC project completed, submitted and accepted.

Matthew Weaver

Host supervisor: Dr Jane Tanner

My research interest lies in sustainable landscape transformation, particularly in addressing complex resource problems at the interface of social and ecological systems. My postdoctoral fellowship has given me the opportunity to drive, support, and research learning processes in multi-collaboration research projects such as the ARUA and Tsitsa Projects. I contribute to various transdisciplinary research processes, including social learning facilitation, capacity development and evaluation, strategic adaptive management, governance, capability expansion, and integrated landscape rehabilitation planning. In the ARUA Project, I have been involved in evaluative research on the Resilient Benefits Project (RESBEN), exploring the value created for participants through social learning engagements.

The ARUA project

I led evaluative research on the Resilient Benefits Project driven by the ARUA Water Centre of Excellence which was implemented using the

Adaptive Systemic Approach (ASA) and involved social learning engagements across six African case studies with the aim of exploring the value created for coordinators, facilitators, participants, and stakeholders involved in the project. The impact of the project was evaluated by exploring the different forms of value created for participants through their engagement in the project. Value was created for project participants as they learnt together during project engagements. How this social learning helped participants to better achieve their work and personal goals can be understood as value. Data on value creation was collected through observation, reflection surveys, analysis of project outputs, and key informant interviews. This research provided a detailed understanding of the value created by the project, which went beyond the initial objectives and deliverables. By focusing on value creation, we were able to showcase the real and lasting impact of transdisciplinary interventions in complex social-ecological systems.

Value creation research findings highlights

Collaborative, effective, and informed teams are crucial for transdisciplinary research to effect transformative change. The research shows how the development of value for different actors in the RESBEN project led to the formation of these teams. Relationships fostered individual development and an increasing understanding of the ASA. These relationships resulted in a deeper transformation, characterised by recognition of the importance of including social science and engaging stakeholders in research. Node Co-Investigators (CoIs) expressed a strong appreciation for working in a collaborative way. The value creation (VC) approach helps to identify different stages of value that ultimately lead to this transformation of identity, which happened at various levels, individually for RAs and early career researchers (ECRs), and was articulated by the CoIs as a collective emergence across the node.

We have collected a large volume of data through the value creation research process and are developing a value creation database to share and publish the findings beyond the RESBEN project. While the analysis of the data continues, I shared and expanded the work through various channels in 2022 and provided training in 2023. The presentations and discussions on value creation have sparked interest and led to the adoption of the approach in other areas and funding proposals. The growing interest in the VC monitoring and evaluation approach has stimulated the demand for training and capacity development in different contexts.

RESBEN Events and stakeholder engagements

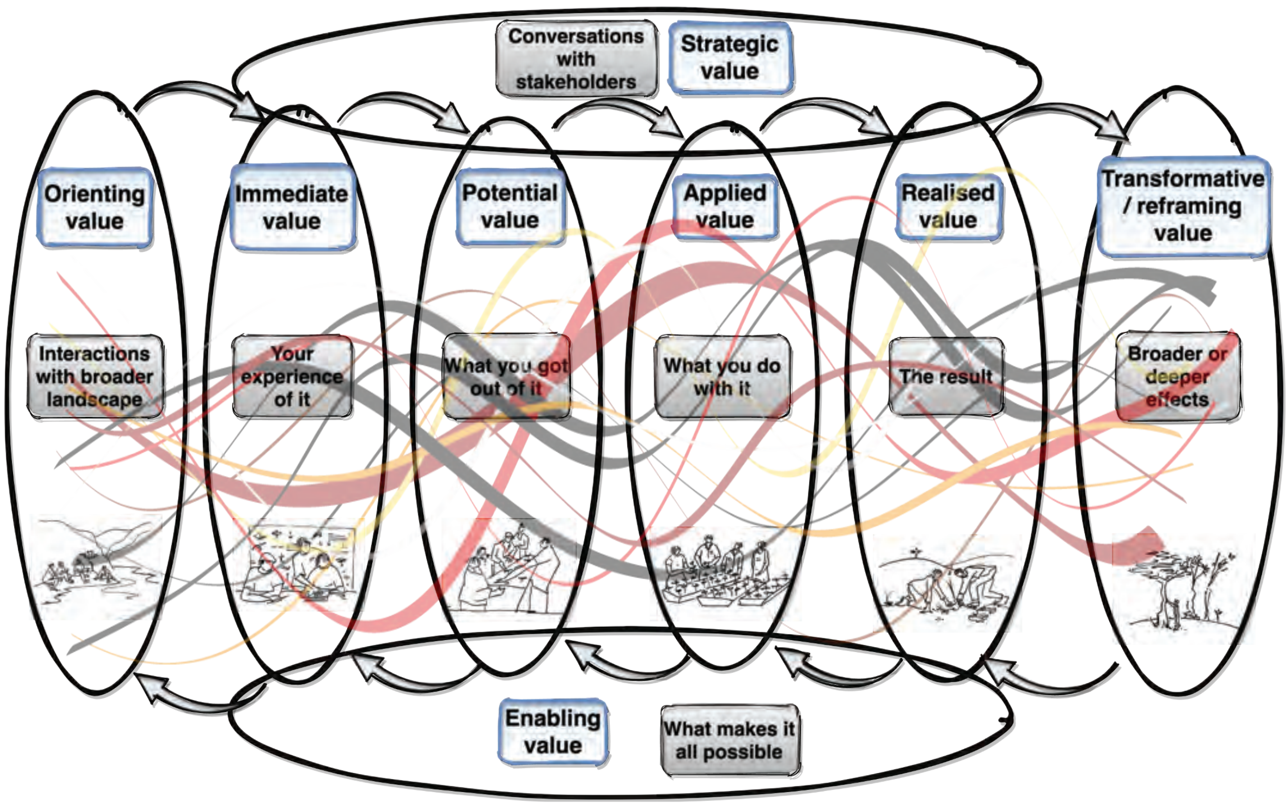
In 2023, six RESBEN country nodes successfully hosted Strategic Adaptive Management workshops. I supported two workshops in Rwanda and Ethiopia, with the Rwandan workshop serving as a learning workshop informing co-facilitation in the other five countries. We also organized a RESBEN Integration Meeting in Uganda, where I led Day 1's activities, capturing narrative stories for ongoing research.

Other relevant highlights

I am working as an editor for an *Ecosystems and People* article collection titled "Advancing transdisciplinary research on social-ecological system transformations in the Global South". The collection explores research and practical efforts for sustainability transformation in complex social-ecological systems. It includes a conceptual framework, innovative methodologies, case studies, and reflections on governance and transdisciplinary practice.

Beyond our exciting research activities, writing funding proposals and co-supervising two Masters students has kept me busy. I have led or contributed to 11 funding proposals, two of which have been successful.

As I move from postdoc to a researcher position, my colleague, Dr Rebecka Henriksson, and I are establishing a water sustainability futures research praxis group at the IWR and ARUA Water CoE. We aim to build a dynamic, multi- and transdisciplinary team dedicated to shifting water-linked sustainability issues towards transformative change.



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.

Using the Rivers of Life methodology as a means of reflection, the RESBEN team shared their journeys through creative depictions of rivers, pinpointing key learnings, challenges and future aspirations.

Nolusindiso Ndara

Host supervisor: Dr Jane Tanner

My time at the IWR was brief but valuable. As a postdoc from January to July 2023, I worked with the ARUA Water CoE RESBEN project which was already in its final year. I also worked on two papers and a proposal.

ARUA Water CoE RESBEN project

As the kickstart of my journey at IWR, I was fortunate to be part of the team traveling to Rwanda to conduct a Strategic Adaptive Management (SAM) workshop where my observations focused on adopting a similar workshop strategy in our respective nodes (I worked most closely with the Nigerian node). After Rwanda, I proceeded to Nigeria where we conducted a two-day SAM workshop, and where I co-facilitated the group sessions and led the team reflection session. In June, I travelled to Uganda where the Makerere team hosted an Integration Meeting, at which all the RESBEN nodes, including the hub, came together to reflect on their personal journey as nodes in the RESBEN project. During the Integration Meeting, I had the opportunity to co-facilitate and learn what each node had achieved through RESBEN. My involvement in the RESBEN project provided me with the opportunity to learn about water-related issues across Africa and what researchers are doing to improve the situation in their respective countries. Coming in as a natural scientist, the project broadened the little knowledge I had in the socio-ecological field, which is an important aspect to incorporate in research.

I left the IWR to pursue a research position at the Expanded Freshwater and Terrestrial Environmental Observation Network (EFTEON). I am grateful to the IWR for hosting me, and preparing me for a position of higher responsibility at EFTEON; for exposing me to the importance of the integration of different disciplines when looking at complex problems, so that we can better understand the bigger picture.

Papers

When I started my postdoc at IWR, I was already working on a paper from one of my PhD chapters. The paper is now currently under review. I was also involved in the translation of an Honours hydrology thesis to a paper, which is still under production.

Proposals

I aimed to submit a proposal for funding to the WRC; unfortunately I left before we could submit it. However, I am grateful for the opportunity to learn how to write a grant proposal. I also submitted a grant application to the NRF for 2024 to 2025.

Rebecka Henriksson

Contract Researcher ARUA Water CoE, RESBEN

Although I have been a new honorary researcher and appointee at the IWR since March 2023, I am not a stranger. I have been involved in the Water CoE and the RESBEN project as a co-investigator and researcher for the UKZN Water CoE node since its start in 2020.

I obtained my doctorate in Sustainability Science through Stockholm Resilience Centre at Stockholm University, and I am based at the Centre for Water Resources Research at University of KwaZulu-Natal. My academic journey has been devoted to building capacity in the practice of transformative social-ecological systems research. My involvement in multiple transdisciplinary projects in Africa has heightened my appreciation of the effort necessary to co-develop shared systems understandings, joint solutions and collaborative actions in addressing sustainability challenges, especially into water scarcity and (in)security, climate change adaptation, natural and water resource management and governance.

Integration within RESBEN and ARUA Water CoE

Transdisciplinary CSES research into sustainability water challenges requires an integrated approach to project design and implementation. RESBEN was designed with such integration in mind, but challenges arose when Node teams implemented the integrated case study plans (see text box). The explorative, iterative "learning-by-doing journey" in RESBEN revealed the need to develop a tool to use as a comprehensive protocol of what to consider, and as a method to systematically assess and analyse integration outcomes of a project. Supported by Prof. Tally Palmer and Dr Matthew Weaver, I developed a tool called the "CSES Integration Wheel" which addresses integration across academic disciplines; knowledge systems (academic and non-academic, including local traditional knowledge); and the science, policy and practice spheres, to ensure equitable impact and lasting change.

The "CSES Integration Wheel" was piloted in RESBEN to assess how and how much CSES integration has taken place in the Node case studies according to five dimensions: 1) conceptual, 2) disciplinary, 3) methodological/analytical, 4) disciplinary/knowledge form, and 5) functional and knowledge sharing. I developed a detailed workbook and led the RESBEN integration assessment during the Integration Meeting in Uganda in June 2023 (see figure 1). Each node assessed their research and stakeholder engagement activities by compiling project-related information for the workbooks, enabling analysis of the integration within and between the dimensions of integration. Encouraging preliminary evidence of wide and deep integration has emerged, as well as unique patterns of integration-success in each country. The varying degrees of integration achieved are to be depicted as wheel diagrams using a colour-scaled scoring system according to specific criteria.

Figure 1. RESBEN Integration meeting in Kampala, Uganda, June 2023. Dr Rebecka Henriksson leading the RESBEN integration assessment (top). Prof. Tally Palmer, Rwanda Node Co-Investigator Dr Venuste Nsengimana and senior researcher Dr Peter Mugume engaging in discussions to populate the Rwanda Node "CSES Integration Wheel" workbook (bottom).

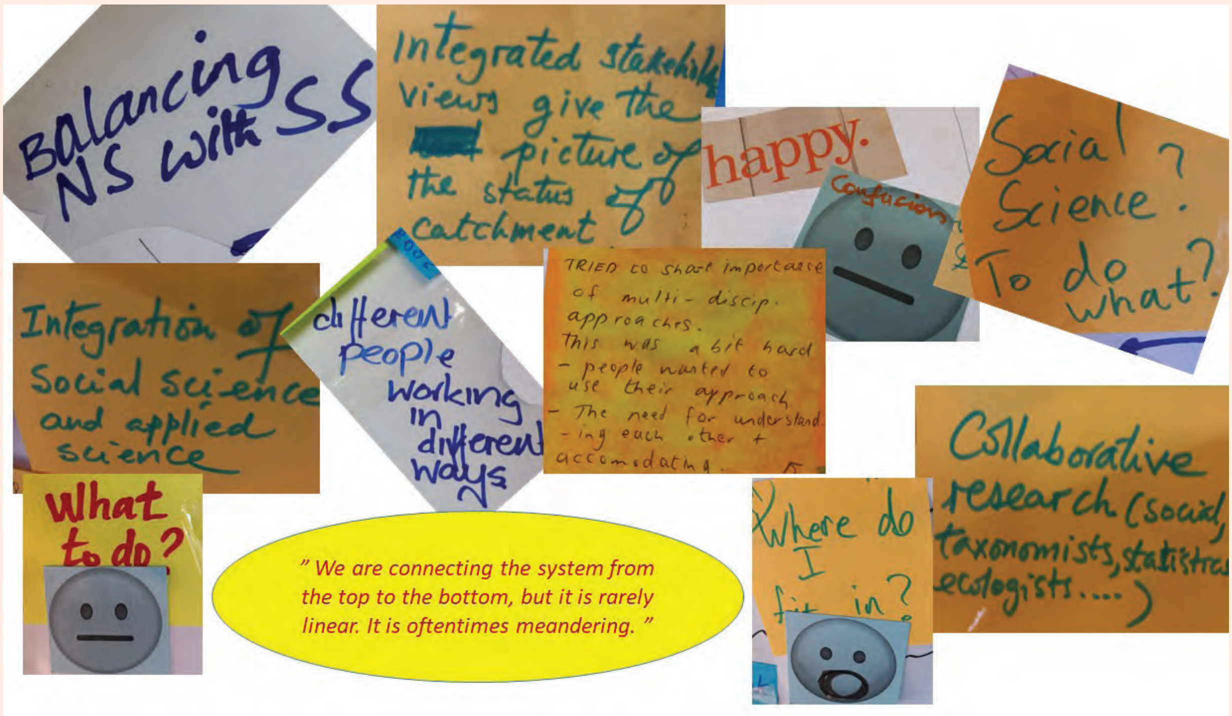
Stakeholder engagement and research support in the RESBEN Senegal case study

The year 2023 started off intensely with the RESBEN Nodes hosting SAM workshops in their case studies. After the Hub facilitators had been part of the initial SAM workshop in Rwanda, I travelled to Senegal with Ms Ntombiyenkosi Nxumalo, a UKZN RESBEN research assistant, to support the Senegal team. We spent time with the RESBEN team at the Université Cheikh Anta Diop (UCAD) in Dakar to plan and provide facilitation training in preparation for the two-day workshop in February. Twenty people from diverse backgrounds, representing a variety of government institutions and local organisations, gathered to co-learn and co-plan a water-secure future of the Lake Guiers basin (Figure 2). It was a delightful to witness the Senegal RESBEN team facilitate the workshop in a manner that created mutual respect and appreciation for the diversity of perspectives and to bridge the various ways of knowing to create a shared understanding of the water security issues.

Lived experiences of reaching the integration goals of RESBEN

"*Where do I fit in?*" asked a senior social scientist of the natural science-dominated RESBEN research team working on improving watershed management in a Central/Eastern African watershed. "*When we bring together social science and applied science we need good methods and processes for data analysis*", responded his biologist colleague, explaining how they embarked on the challenge together. "*How do we get decision-makers to join the process and how will local stakeholders realise they are an important part of the problem-solving?*" were other questions raised when reflecting on the planning phase of RESBEN, aimed at establishing participatory water governance in a West African lake basin. "*We were nervous about the process*", confessed a Southern African water management specialist and continued, "*We wanted to learn first, before engaging people*".

Below is a representation of some encounters facing the RESBEN research teams embarking on a joint transdisciplinary journey to integrate complex social-ecological systems in various water sustainability contexts. These challenges are not unique. Social-ecological systems research exhibits a notable insufficiency of overall integration, pertaining to persistent obstacles in integrating different disciplines, various knowledge systems, and between academic and societal modes of operating within the context of sustainability problems. These obstacles are part of the complex nature of the issues addressed through RESBEN, and presented a challenge for the Node teams in their journeys to apply the Adaptive Systemic Approach in their respective case studies.



A collection of thoughts and reflections about the journey of integration within RESBEN, gathered through a River of Life exercise with Co-Investigators and senior researchers during the RESBEN Integration meeting in Kampala, Uganda, in June 2023.

Figure 2. SAM workshop, Saint Louis, Senegal, February 2023. Ms Ntombiyenkosi Nxumalo and Prof. Alioune Kane facilitating a group exercise (top), and Dr. Djim Diongue provides translation between French and Wolof, as one of the participants gives feedback on the objectives hierarchy from their group session (bottom).

The ASA in Senegal has resulted in an impressive ensemble of research and stakeholder engagement outputs and outcomes led by Prof. Serigne Faye and Prof. Alione Kane and their team of early career researchers and research assistants. I undertook to lead the development of a paper for the RESBEN special feature, demonstrating the potential of the ASA application to initiate a trajectory of change towards water security of the Lake Guiers basin. The author team, which includes the entire Senegal team, participated in a tailor-made course in Systems Modelling and Causal Loop Diagramming organized by IWR associate Dr Jai Clifford-Holmes in September and October 2023. The course resulted in developing the skills of the team, and also in modelling the basin as a complex social-ecological system, identifying critical system components, key drivers, and feedback mechanisms to inform strategic interventions towards a water-secure Lake Guiers basin.

I look forward advancing our understanding and practice of integrated CSES research for sustainability. The year 2024 offers exciting avenues for this, such as the finalization of the Ecology and Society Special Feature, the ARUA-Guild Cluster of Excellence in Water Resource Management for a Sustainable and Just Future, and the ARUA joint Doctoral school programme, “Africa’s Water Future”.

Student project reports

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

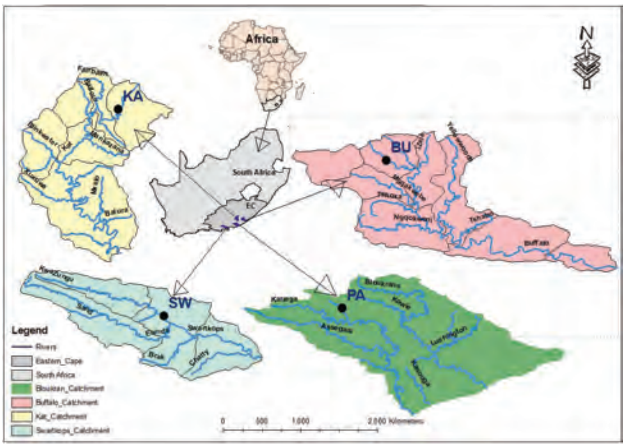
Student: A.A. Ali
Supervisors: O.N. Odume and C.F. Nnadozie
Degree: MSc (Water Resource Science)

Emerging pollutants, such as plastics, are threat to freshwater ecosystems. They can modify riverine habitats and affect aquatic organism distribution and composition. Because knowledge of how macroplastics alter riverine habitat heterogeneity and their effects on macroinvertebrate assemblage structure is sparse, especially in Africa, this study examines the effect of hydraulic biotopes on the colonisation, establishment and succession patterns of macroinvertebrates on macroplastic and natural substrates. Four experimental sites from minimally impacted upper reaches of the Buffalo, Kat, Kowie, and Swartkops Rivers in the Eastern Cape of South Africa were selected to deploy plastic substrates (Figure 1). Plastic materials, including polyethylene terephthalate (PET) bottles and natural substrate composed of stone and vegetation, were used to formulate three substrate groups: 100% natural substrates (NS), 50% natural substrates and 50% plastic material (NP), and 100% plastic materials (PD). These substrates were placed in litterbags and deployed randomly in three hydraulic biotopes (pools, riffles, runs) over a period of 180 days (October 2021 – April 2022). The taxonomic and trait-based approach was used to analyse the establishment of macroinvertebrates on macroplastic substrates.

The result showed that both macroplastic and natural substrates supported the colonisation and establishment of macroinvertebrate communities. All macroinvertebrate taxa recorded showed non-significant positive correlations with all three substrate groups, except, Tabanidae, Glossosomatidae, and Psephenidae, which showed significant positive correlation with the 100% natural substrates, 50% plastic substrates and 100% plastic substrates, respectively.

For the pool biotope, Shannon and Simpson indices were significantly higher ($P < 0.05$) for the macroinvertebrates collected over the natural substrates than those collected on the macroplastic substrate. However, in the riffle and run biotopes, all diversity indices were similar for all substrate groups and no statistically significant difference was observed.

Traits such as oval and flat body shape, medium body size (>10–20 mm), skating and clinging/climbing mobility, temporal attachment, shredders, predators, prey, and plastron and spiracle respiration showed positive correlation with the 100% macroplastic substrates. Filter feeding, crawling, permanent attachment, a preference for fast velocity (0.3–0.6 m/s), and coarse particle organic matter were positively correlated with the 50% macroplastic substrates. Overall, the results provided critical insights on the impact of macroplastics on the assemblage structure of biological communities by acting as suitable habitats in stream ecosystems. Macroplastic may displace natural riverine habitats and with all its detrimental effects, impact resident organisms.



Four selected study sites in their catchments in the Eastern Cape, South Africa.

Andrew Ali on community engagement duty with River Rescue, cleaning the river.

Leverage points for meaningful participatory governance: lessons from the Tsitsa River catchment, South Africa

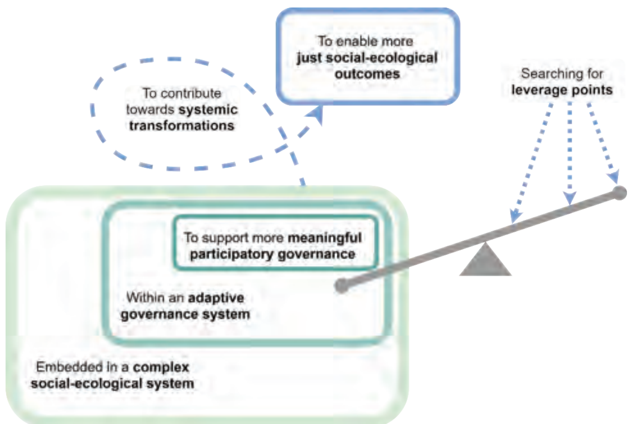
Student: A.S. Fry
Supervisors: C.G. Palmer and J.K. Clifford-Holmes
Degree: PhD (Water Resource Science)

South Africa became a representative, multiracial democracy in 1994. While there has been notable progress in many developmental aspects of South African society, many inherited dilemmas persist, and myriad novel ones are emerging. In 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 persist: widespread failures in local water governance, inequality of access to land and water, poor or non-existent service delivery in rural areas, underdeveloped institutions for integrated and inclusive water resource management, pernicious divisions between institutions. Overcoming these challenges embedded in complex social-ecological systems across South Africa, requires the collaborative effort of diverse actors from different levels and sectors of society.

How do we foster meaningful participation in ways that are not tyrannical, tokenistic, or manipulative? How do we build local institutions that make sense in the broader political system and in the lives of rural residents? How do we support institutions that meaningfully include diverse voices and enable tangible development outcomes? This thesis explored these questions as part of the Tsitsa Project, a transdisciplinary landscape management project working in the Tsitsa River Catchment (TsRC) in the rural parts of the Eastern Cape province of South Africa. Based on the valuable water resources, severe ecosystem degradation, overlapping traditional and democratic governance systems, and impoverished population, the TsRC is a worthwhile candidate for in-depth study paired with innovative efforts towards systemic development.

The single place-based case study approach drew on systems thinking within an evolving transdisciplinary methodology. Qualitative data were collected through extended fieldwork and analysed through an adaptive and iterative approach. Governance mapping elucidated the multiple levels of governance, and a systemic analysis explored meaningful participation at the local level through causal diagramming and observation-based narratives. The findings generated a synthetic analysis identifying high leverage points to enable participatory governance interventions to have more sustained impacts.

Governance manifestations in the TsRC generally align with existing descriptions of the fractures and associated dilemmas across South Africa, with the added complexity of a rural landscape in which democratic and traditional governance systems overlap and interact. Local participatory institutions need to endure the broader instability and dysfunction, and interventions must therefore be oriented towards trust building and shared understanding while using more practical interventions that provide tangible outcomes enable in-practice capacity development, and support platforms for all actors to experience and practise meaningful participation together. This research aimed to unearth the lessons that one small rural catchment might hold for the governance of complex, contested land and for water governance contexts more broadly.



Conceptual overview. In this research, I search for leverage points to support meaningful participatory governance, within an adaptive governance system, embedded in a complex social-ecological system. This process aimed to contribute towards systemic transformations to enable more just social-ecological outcomes.

Tsitsa River Catchment Terrain. Grasslands dominate the landscape. Large erosion gullies are in the riparian zone. (Source: Anthony Fry).

Participants in a participatory workshop which formed part of the Tsitsa Project's work building participatory governance capabilities in the Tsitsa River Catchment (Source: Anthony Fry).

Mapping key driver of ecological change and analysing equity dimensions of the ecosystem services flows in the Kat River catchment.

Student: E.A. Seriki
Supervisors: O.N. Odume, C.F. Nnadozie, and C. Murata
Degree: MSc (Water Resource science)

The Kat River is a tributary of the Great Fish River in the Eastern Cape of South Africa and is the main source of water for the Kat River catchment. The Kat River has its origin in the Hogsback mountains and courses between Seymour and Fort Beaufort. The principal tributaries of the Kat River include Balfour, Fairbairn, and Blinkwater streams, and one minor tributary, the Xwentxe stream, which flows into the Kat River Dam at Cathcartvale and Seymour. The Kat River holds vital socio-economic importance for the Nkonkobe Municipality, providing water for agriculture, including crop irrigation and livestock farming. It also serves as a site for spiritual activities, and it supplies water for domestic needs like drinking, bathing, and laundry. However, the Kat and its tributaries are typically ephemeral, frequently lacking a reliable water supply during dry seasons and drought years. Besides, the Kat River catchment is heavily impacted by human activities, the river is polluted by sewage and alien invasive species, leading to diverse ecological changes. The catchment faces various socio-ecological concerns, such as disproportionate access to ecosystem benefits provided by the river, and lack of access to reliable water supply by some social classes, especially resource-poor households who cannot afford water treatment chemicals, such as domestic bleaches.

The equitable flow of ecosystem services in society is critical to sustainable development. To gain a nuanced understanding of this social-ecological complexity, an in-depth study was required. This study focuses on the key drivers of ecological changes, the impacts of the ecological change on ecosystem services, and finally analyses distributive and procedural equity dimensions of ecosystem services in the catchment. A Participatory Geographic Information System (PGIS) mapping method is used to explore key stakeholders' perceptions of the ecological change, its drivers, and ecosystem services. The spatial-temporal dimensions of the perceived ecological changes and identified ecosystem services were also examined. Semi-structured interviews were used to assess equity dimensions of the flow of ecosystem services in the catchment. The results obtained so far are presented in Figure 1 which shows some perceived ecological changes in the catchment and the severity of their impact ratings on livelihoods.

Results from the semi-structured interviews revealed concerns regarding the flow of ecosystem services among social groups in the catchment. With regard to the allocation of water from the Kat River, more than 70% of the respondents pointed out that farmers consume a high volume of water from the river, and the group of people who benefit least are the disabled and old since they lack the means of reaching the river.

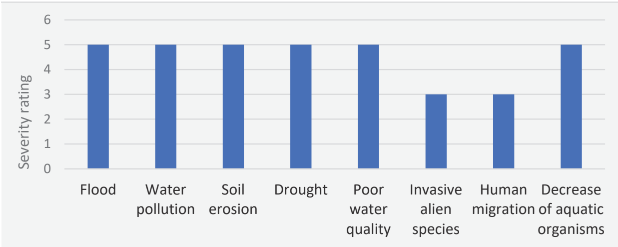


Figure 1: A representation of the perceived severity impact of the identified ecological change. (1= not serious, 3 = moderately serious, and 5 = very serious).

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

Student: E. Tumwesigye
Supervisors: O.N. Odume, G.W. Nyakairu, and C.F. Nnadozie
Degree: PhD (Water Resource Science)

Background

Water resources in South Africa support human well-being, livelihoods, and sustainable urban development by supplying desired and valued ecosystem services. Recently, plastic proliferation has been indicted as one of the major threats to freshwater resources in the country because of its negative impacts, such as severe water quality degradation, the toxic effects on aquatic biodiversity and potential human health risks Plastics propagate emerging toxic organic pollutants in freshwater ecosystems because they disintegrate into small fragments called microplastics (MPs) which can interact with ambient toxic chemicals owing to their increased surface area to volume ratio, so acting as conduits for harmful chemicals that can bioaccumulate across food-chain organisms.

Knowledge of the interaction between MPs and contaminants of emerging concern (CEC), specifically pharmaceuticals, in freshwater ecosystems and the consequent ecological and human health risks in freshwater landscapes in South Africa is limited. In order to understand interaction between MPs and contaminants, as well as the risks associated with MPs and the associated emerging toxic chemical pollutants, this study: i) investigates the effects of selected plastic properties and spatial-temporal variability on the adsorption of selected pharmaceutical pollutants on microplastics; ii) determines the influence of selected physio-chemical variables on the adsorption of pharmaceutical pollutants on microplastics; iii) explores the kinetic adsorption processes between the selected pharmaceutical pollutants and microplastics and the influence of plastic transport, transfer and retention dynamics on the adsorption and release of toxic organic contaminants, and iv) develops a conceptual framework for incorporating the vector in the risk assessment of microplastics.

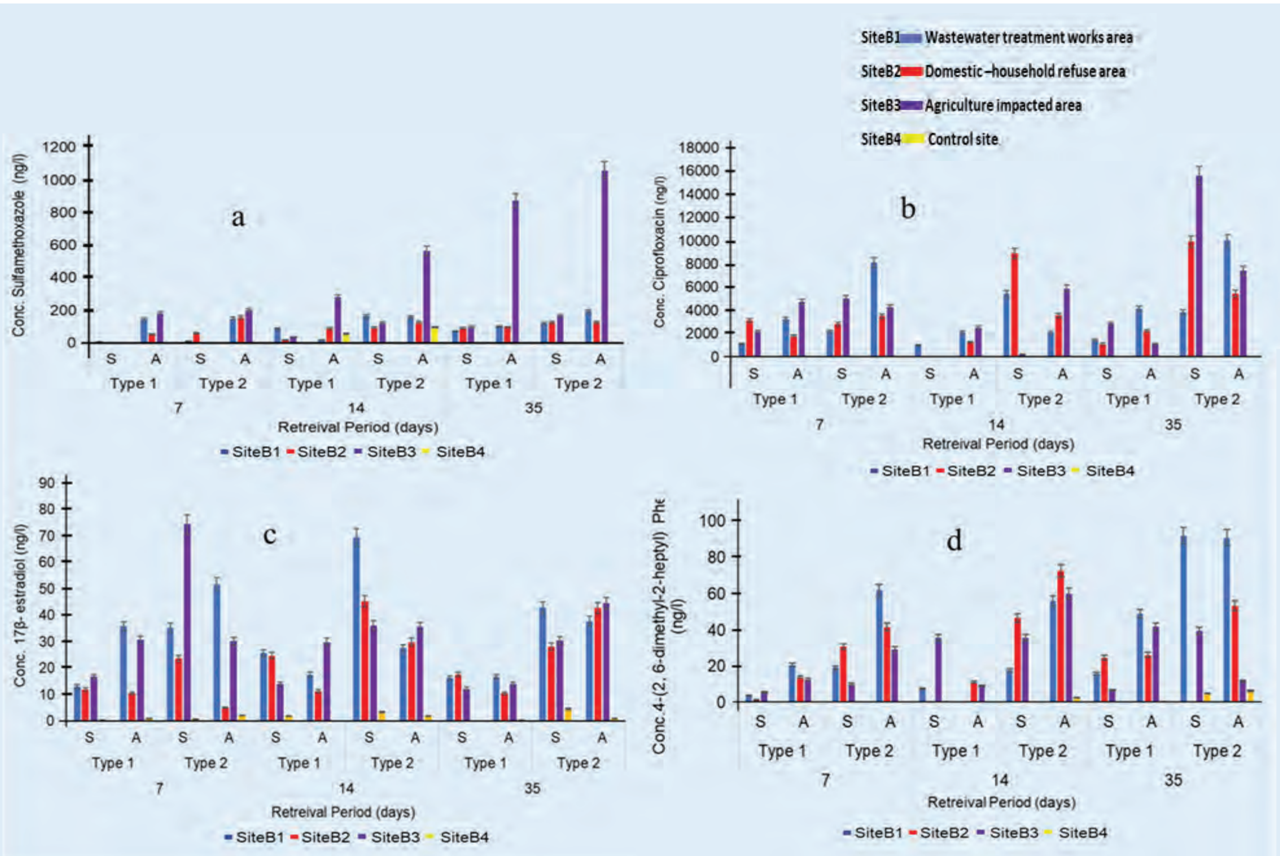


Figure 1: Spatial, temporal and seasonal variability of adsorbed concentration of Sulfamethoxazole (a), Ciprofloxacin (b), 17ß-Estradiol (c) and 4-(2, 6-dimethyl-2-heptyl) Phenol (d) onto PET Type-1 and Type-2 MPs at the four study sites: B1, B2 and B3 in the Bloukrans River, with B4 on Palmiet River over two seasons, S = summer and A – autumn during the study period. Standard error (bars).

Methodology

We used field experimentation (*in-situ* deployment) of microplastic pellets of two size ranges: Type 1 (2mm<-≤5mm), and Type 2 (0.5m<-≤2mm) produced by bleeding the environmental retrieved plastics. After a period of 7, 14 and 35 days the MPs were retrieved, placed in cooler boxes and transported back to the water quality laboratory of the Institute for Water Research (IWR), Rhodes University, South Africa. The extraction of the targeted compounds on the MPs was done within 24–48 hours after each retrieval.

Tentative results

Preliminary results indicated a significant correlation between MP size, land-use along the freshwater system where the MPs are located, and the concentration of pharmaceuticals adsorbed to MPs. The small Type-2 sized MPs and those retrieved near the WWTP had higher amounts of associated ciprofloxacin than those from other sites (Figures 1 and 2). The MPs retrieved from sites impacted by agricultural activities had a significantly higher amount of sulfamethoxazole than the other targeted antibiotic. However, no significant differences ($p > 0.05$) in the MP adsorption capacity and seasonality (temporal factor) (Tukey's HSD) was observed (Figure 3). The findings from this study justify the conclusion that spatial-temporal variations can act as drivers of microplastic distribution and abundance, so influencing MP-pollutant interaction.

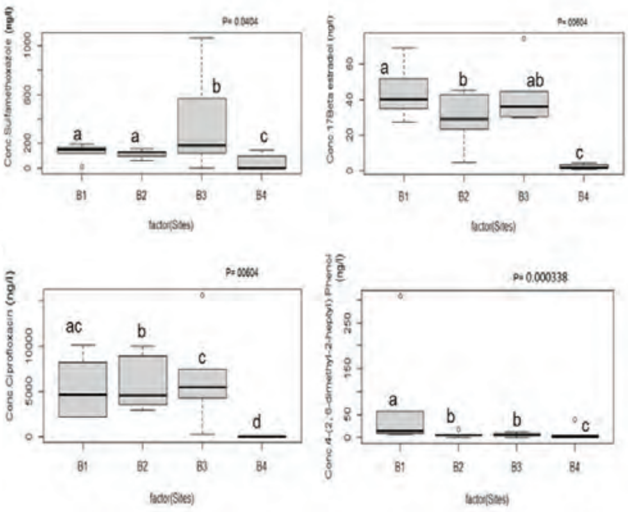


Figure 2: ANOVA (box-plots) -factor (sites) for the mean concentration of Sulfamethoxazole, Ciprofloxacin, 17ß-Estradiol and 4-(2, 6-dimethyl-2-heptyl) Phenol adsorbed onto the PET Type-2 microplastics at the four study sites in the Bloukrans Rivers (B1, B2, B3) and Palmiet Rivers (B4) during the study (December 2021 to May 2022 – summer to autumn). The same alphabet letter on the bars indicates no statistically significant difference (P > 0.05), whereas different alphabet letters show statistically significantly difference (P < 0.05).

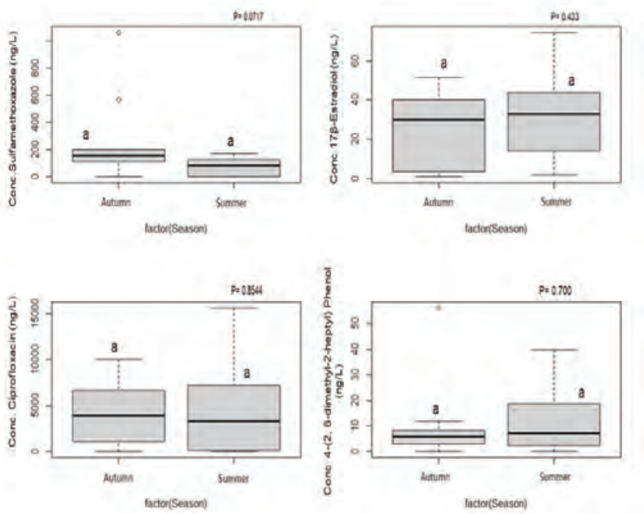


Figure 3: ANOVA (box-plots) -factor (seasons): Seasonal variability for the mean concentration of Sulfamethoxazole, Ciprofloxacin, 17ß-Estradiol and 4-(2, 6-dimethyl-2-heptyl) Phenol adsorbed onto the PET Type-2 microplastics in the Bloukrans Rivers (December 2021 to February 2022 – summer, March 2022 to May 2022 – autumn). The same alphabet letter on the bars indicates no statistically significant difference (P > 0.05), whereas different alphabet letters show statistically significantly difference (P < 0.05).

A mechanistic and trait-based approach to investigating macroinvertebrate distribution and exposure to microplastics in riverine systems.

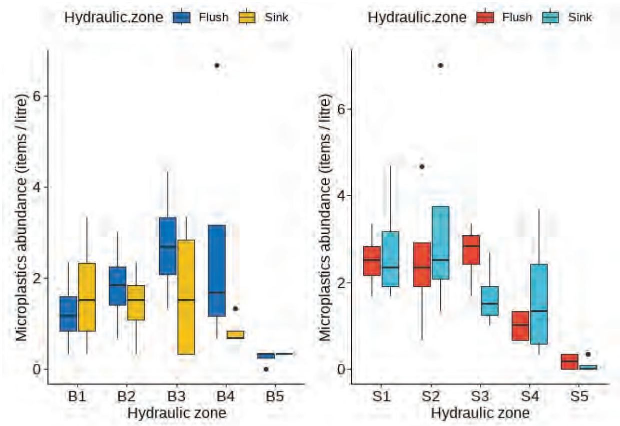
Student: E.K. Owowenu
Supervisors: O.N. Odume and C.F. Nnadozie
Degree: PhD (Water Resource Science)

Microplastics pollution in global aquatic systems is increasingly becoming a concern as it may impact biota such as macroinvertebrates. Microplastic particles <5mm in diameter have a widespread distribution, with a large volume of literature demonstrating several ecological effects. Laboratory and field-based occurrence studies show that the ingestion of microplastic particles can affect aquatic organisms, including zooplankton, invertebrates, fish, and birds. Most of these studies investigated macroinvertebrates, probably because of their overwhelming influence in freshwater ecosystems worldwide. However, these studies were not designed to consider hydraulic biotope distribution/patchiness, yet hydraulic biotope patchiness influences the distribution of aquatic organisms such as macroinvertebrates and, thus, their potential exposure to microplastics.

Rivers are characterised by different flow environments and hydraulic patterns which result from the interaction between flow, substrate, and channel morphology. Hydraulic biotopes have been used to describe different instream flow environments composed of very fast (e.g., rapids) or slow-flowing (e.g., pools) patches creating a picture of "flush and sink zones". Thus, hydraulic biotopes impact the distribution of microplastics and create different concentrations of microplastics in each flow patch; that is, a fast-flowing patch creates a microplastics flush zone, while a slow-flowing patch develops as a microplastics sink zone.

Traits mediate organism-environment interaction; that is, a set of traits determines where a species is able to live and so a trait may provide a rational, mechanistic understanding of species-environment relationships. This understanding suggests that macroinvertebrates that select a microplastics 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 that prefer a microplastics 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 seen as key to achieving the goal of predicting an organism's response to environmental change, as well as diagnosing and discriminating between environmental stressors through mechanistically linked traits. Thus, hydraulic biotope distribution/patchiness, traits, and ecological preferences of organisms are important biophysical factors critical to understanding the risk posed by microplastics on macroinvertebrates.

The study investigates macroinvertebrate distribution and exposure to microplastics in riverine systems using a mechanistic and trait-based approach. The methodological approach involved the delineation and characterisation of hydraulic zones, and sampling at the hydraulic biotope scale. Preliminary results based on global multivariate analysis of variance indicate a significant effect of hydraulic biotopes on the spatial and temporal distribution of settled microplastics.



Spatial distribution of microplastics particles at each site across the hydraulic zones (left – Buffalo River; right – Swartkops River)

E.K. Owowenu on a field-sampling exercise

Molecular assessment of the impact of plastic pollution in selected rivers in the Eastern Cape on emerging antibiotic-resistant infections

Student: H.O. Nnadozie
Supervisors: C.F. Nnadozie and O.N. Odume
Degree: MSc (Water Resources Science)

An estimated 1.4 million metric tons of plastic are used across South Africa annually, making South Africa one of the top 20 countries contributing to aquatic plastic litter each year. Plastic debris is introduced into receiving freshwater through surface runoff, treatment plant discharges, industrial effluents, atmospheric deposition, and direct littering and dumping.

When plastic debris enters aquatic environments, microorganisms can rapidly colonise their surfaces and form biofilms. Some studies have found that plastic surfaces also concentrate antibiotic-resistant genes (ARGs) from the surrounding water, potentially influencing the prevalence and persistence of pathogens and ARGs, and plastics in aquatic environments can serve as a significant and enduring repository for pathogens, carrying substantial implications for both epidemiology and ecology.

As plastics exhibit remarkable persistence, they can act as a potent reservoir for infectious agents, introducing new pathways of infection that heighten the risk to both humans and animals. Additionally, the long lifespan of plastics enables pathogens to accumulate on their surfaces over time, amplifying the environment's capacity to harbour these pathogens. Horizontal gene transfer may transfer these ARG competent bacteria that colonise the plastisphere, and such pathogens may hitch-hike on the floating plastic particles, expanding their geographical range, and acting as artificial 'super-spreaders'.

This study demonstrates the impact of plastic pollution on the accumulation of pathogens and their antibiotic-resistance genes, which has several ecological and epidemiological implications.

Two potential pathogenic species are emphasised: *Vibrio* sp. and *Campylobacter* sp. The selected pathogens survive in the environment and are known to cause gastroenteritis. According to the World Health Organization (WHO), foodborne and diarrheal diseases affect 600 million people annually, with 420,000 deaths. In 2023 alone, there have been 1,290 suspected cases of cholera caused by the pathogen *Vibrio cholerae*, with 47 deaths recorded. Similarly, a 2017 study on the surveillance of *Campylobacter* in South Africa showed a 94.5% prevalence of *Campylobacter* sp. in samples collected from different provinces across the country.

Surprisingly, there is a lack of environmental surveillance and research to monitor the presence of potentially pathogenic bacteria in water bodies in South Africa. The colonisation of plastics by such organisms is a threat to public health, as it increases the risk of outbreaks of antibiotic-resistant infections that are difficult to treat.

The study aimed to i) investigate the contamination levels of plastic debris in urban rivers in Eastern Cape, South Africa; ii) investigate the ARB and ARG diversity of selected urban rivers in the Eastern Cape; iii) evaluate the role of plastic-associated biofilms as vectors of pathogenic bacteria and their associated ARGs in freshwaters.

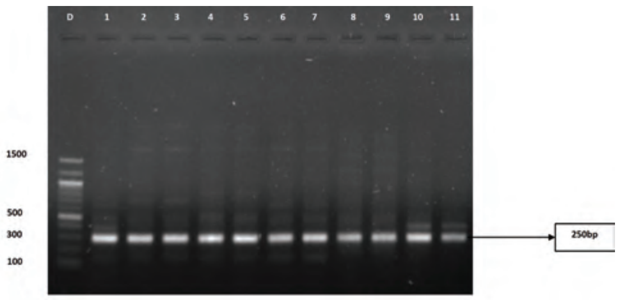
Study progress

The Swartkops and Kat Rivers in the Eastern Cape were sampled across two seasons (summer and winter) to estimate the abundance of plastic waste and the microbial diversity of surface water and plastic biofilms.

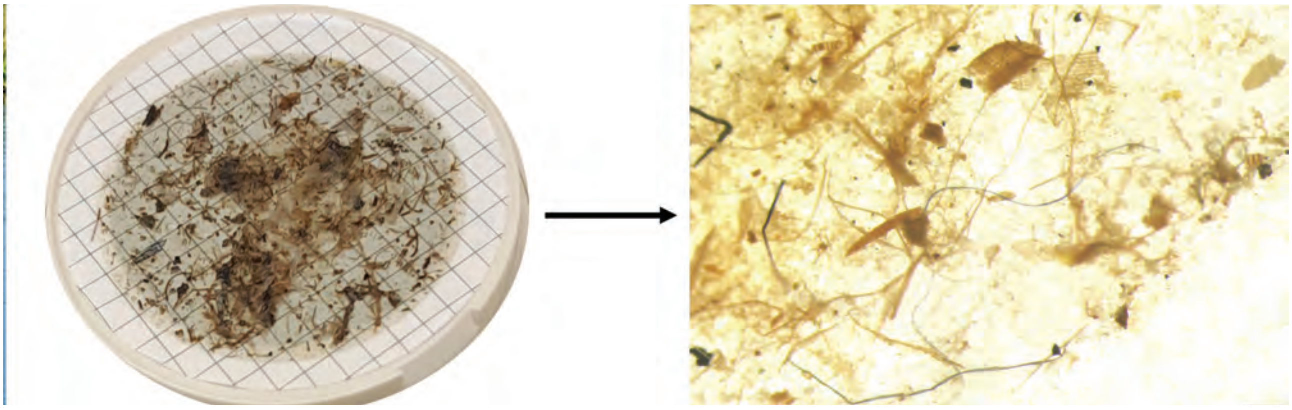
Preliminary findings

Macro- and microplastics were detected in the rivers. Molecular analysis revealed the presence of the target pathogens, *Vibrio* sp. and *Campylobacter* sp., and their antibiotic-resistant genes in the surface water and their accumulation in plastic biofilms.

Student collecting microplastic samples from the Swartkops River during a sampling campaign in July 2023



Agarose gel electrophoretic analysis of the PCR products for the detection of 16S rRNA from plastic biofilms in the Swartkops and Kat River



Microplatics particles recovered from surface water samples in the Swartkops River were visualised using Light Microscopy

Plastic debris showing development of biofilms recovered from surface water in the Swartkops River

Integration of satellite data in reducing hydrological modelling uncertainty for sustainable water resources management in sub-saharan Africa

Student: H.A. Okal
Supervisors: J.L. Tanner and S.K. Mantel
Degree: PhD (Hydrology)

Introduction

Sub-Saharan Africa (SSA) faces an acute scarcity of essential weather, climate, and hydrological data, creating a critical barrier to progress in vital sectors such as water resource management, flood control, and irrigation. Declining funding and deteriorating monitoring networks exacerbate these challenges, resulting in a heavy reliance on unvalidated model outputs for decision-making, which poses environmental and socio-economic risks and undermines trust in modelling. Hydrological constraints, encompassing essential parameters for water resources management, environmental conservation, and infrastructure planning provide valuable insights for informed decision-making. This research confronts these data scarcity challenges by addressing issues related to model complexity, knowledge gaps, and validation challenges. Complex models, inaccessible software, a lack of local expertise, and limited observational data hinder the effective use of hydrological models.

Research aim and specific objectives

The research focuses on the challenges associated with implementing local models in data-scarce regions. Specific objectives include: i) identifying regions in SSA where information exists and where local capacity was involved in information gathering and the modelling process; ii) using outputs from local modelling studies to validate outputs from Global Hydrological Models (GHMs); iii) exploring constraints within the existing Pitman Model configurations to create Hydrological Signatures (HS) for diverse SSA regions, and iv) leveraging Remote Sensing (RS) technology to bridge data gaps and provide water balance estimates derived from satellite data.

Methodology

For objective (i), a systematic literature review covered hydrological modelling studies in SSA's 12 major river basins from 2000–2022. Objective (ii) involved reviewing studies that compared and validated GHMs in SSA. For objectives (iii) and (iv), the ERA5-Land runoff dataset was validated against locally observed data from WR2012 in Eswatini's 73 quaternary catchments during the overlapping timeframe of 1950–2010. Various analyses, including timeseries plots and flow duration curves, were performed. Constraints derived from both data sources were compared with those from Coli Ndzabandzaba's 2021 study.

Research Outputs

1. Information reliability and local capacity building: Out of 205 studies, only 30 incorporated *in-situ* data for modelling, and 77 demonstrated signs of local capacity development.
2. Validating global hydrological models: The review highlighted the insufficient validation of GHMs outputs, rendering them unreliable.
3. Unlocking Remote Sensing data: The study compares ERA5-Land runoff data in Eswatini, with a local modelling study undertaken using WR2012 data.
4. Constraint-based Hydrological Signatures: The study investigates whether constraints derived from remote-sensed data are comparable with observed or modelled data, and whether those constraints could be used to validate hydrological models in the future, or can be used for water resources management decisions.

Conclusion

Data scarcity and the limited development of local capacity pose significant threats to sustainable water resources assessment and management in SSA. This research contributes to sustainable water resources management, climate adaptation, and a deeper understanding of the intricate hydrological dynamics in SSA's catchments.

Harriette Okal's poster presentation at the European Geosciences Union General Assembly 2023, Vienna, Austria

Aspects of the water use of *Cannabis sativa l.* under dryland and tunnel cultivation in the Eastern Cape

Student: K.T.S. Zenani
Supervisor: A.R. Palmer, K.G. Smart, and S.K. Mantel
Degree: MSc (Water Resource Science)

Originating in Asia, *Cannabis spp.* is one of the oldest cultivated plants. Its genus has two recognized species, namely, *C. indica L.* and *C. sativa L.* This research focuses on *C. sativa,* which is widely cultivated locally and globally. The global interest has led many governments to review the laws governing this plant as it is a controlled substance in many countries. Despite its legal status, there is a dearth of knowledge about its growth and water use. In recent years there has been a growing interest in increasing its cultivation, but it is reported to require large quantities of water. It is against this backdrop that the Water Research Commission (WRC) commissioned this study into the water use of this plant.

Our research measured the water use under dryland cultivation, providing evidenced-based support for issuing water-use licences by the Department of

Water and Sanitation. The Eastern Cape and KZN have many small-scale legacy farmers who have been growing *Cannabis* illegally for decades. The findings of this research seek to fill some of these gaps and help the legacy farmers expand their operations.

Our study measured evapotranspiration using a Large Aperture Scintillometer (LAS) and a hand-held leaf porometer. The data obtained was used to model the total amount of water used by *C. sativa*. In order to simulate the conditions of a small-scale farmer in the rural Eastern Cape, the study used very few inputs. The research had four approaches which included: i) planting the crop in a dryland location that mimicked the conditions experienced by legacy growers; ii) collecting the plant parameters in both a dryland and rain-fed field in order to gain a better understanding of the plant's health, growth and progress; iii) installing a large aperture scintillometer together with a micro-meteorological station to measure the evapotranspiration (ET) over a crop cycle, and iv) using a MEDRUSH transpiration model to predict the ET.

Figure 1: Cannabis sativa plants in growing bags at Firglen (20 October 2022) and in germination trays (2 September 2022).

Soil nutrient status and water provision had a significant impact on plant biophysical variables and water use. In the rain-fed field trial, plants received 154 mm (2 mm day^{-1}) of rain during the crop cycle. The large aperture scintillometer recorded a total ET of 126.8 mm (1.79 mm day^{-1}) during the same period. In the field trial, plants performed best in deeper, high-nutrient soils. They had a higher leaf area index, width, height and stomatal conductance and were more vigorous than those that were grown in nutrient-deficient soils. The MEDRUSH model (2.5 mm day^{-1}) slightly over-estimated the LAS ET (1.79 mm day^{-1}), and the results from the daily ET revealed that *C. sativa* had higher daily ET than the local grass, *Eragrostis plana*. These results confirm that *C. sativa* requires regular irrigation in order to grow and produce a crop.

Context-related drivers, occurrence and human exposure to antibiotic resistant *Campylobacter* in selected river systems in the Eastern Cape, South Africa

Student: M. Chibwe
Supervisor: C.F. Nnadozie and O.N. Odume
Degree: PhD (Water Resource Science)

The occurrence of Antibiotic-Resistant Bacteria (ARBs) and Antibiotic-Resistant Genes (ARGs) in water bodies, including rivers, is a global concern as the ARBs can be transmitted to humans upon exposure to contaminated water. *Campylobacter* species are among the leading etiological agents for gastroenteritis in humans worldwide. Antibiotic-resistant pathogens, such as *Campylobacter* and other pathogens, lead to increased hospitalisation and mortality rates as infections caused by ARBs are becoming difficult to treat. Globally, *Campylobacter spp.* have shown resistance to macrolides fluoroquinolones and tetracycline.

Previous studies indicate *Campylobacter* infections may be endemic in South Africa. However, the contribution of local rivers to human infections with *Campylobacter* and the relative importance of the various transmission routes is unknown. Quantitative data on the exposure of humans to *Campylobacter* through the various transmission routes is lacking, and important knowledge gaps remain on *Campylobacter* dynamics in surface water and the link with environmental conditions and seasons in South Africa. Risk of emergence, selection and transmission of ARBs and ARGs in rivers is multidimensional and therefore requires a holistic approach that integrates environmental conditions with social and economic dimensions. This project investigated the context-related drivers, and the occurrence and human exposure to antibiotic-resistant *Campylobacter* in selected river systems in the Eastern Cape, South Africa.

This study employed a questionnaire survey to collect data on the context-related drivers of the emergence and transmission of antibiotic resistance at catchment level. River water samples were collected, processed and analysed using standard polymerase chain reaction (PCR) and quantitative PCR.

Results showed that the spread and emergence of antibiotic resistance is driven by social and economic factors in these catchments. *Campylobacter* was detected at sites that are impacted by wastewater, livestock and other anthropogenic activities throughout the year. The human intake burden for *Campylobacter* and ARGs recorded in this study suggests that human exposure to water in the Swartkops and Bloukrans rivers may lead to ingestion of high concentrations of antibiotic-resistant *Campylobacter* and ARGs resulting in infection and/or colonisation in humans. Results from this study have been presented at local and international conferences. The research outputs for this project so far include two published papers, one paper in the final review stage, and a chapter under review for publication in a book by UNESCO.

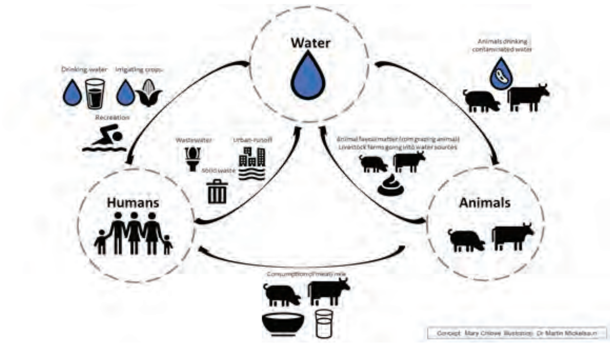


Figure 1: Transmission of Campylobacter and ARGs between water, humans and animals

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

Student: M.O. Osoh
Supervisors: O.N. Odume and C.F. Nnadozie
Degree: PhD (Water Resource Science)

Although freshwater ecosystems, such as rivers and streams, are important sources of water for living organisms, most freshwater systems in the urban catchments of South Africa are severely degraded by human-induced pressures. Critical knowledge gaps in water resources management in urban landscapes, coupled with the increasing human population, have resulted in the proliferation of urban infrastructures that have severe consequences for ecological systems. The need to adequately manage and protect freshwater resources is crucial to ensuring the supply of ecosystem services.

The widely used macroinvertebrate-based assessment tool in South Africa is the South Africa Scoring System version 5 (SASS 5). Although this tool enables a rapid bioassessment of riverine systems, it is based on a family-level taxonomic resolution of aquatic macroinvertebrates and does not account for families which possess great diversity, such as the Chironomidae, raising questions about the validity and accuracy of results obtained from this tool.

Chironomidae are among the most diverse macroinvertebrate families, possessing a wide ecological range and having the ability to survive in natural and degraded water systems. The differential responses of chironomid species to human-induced pressures such as increased organic loadings, flow alteration, and sediment input can be investigated to better understand the impact of pollution in urban river systems. This study aimed to investigate the application of the taxonomic and functional characteristics of chironomids in the assessment of cross-scale filters of urban pollution in selected urban rivers in Eastern Cape, South Africa.

The objectives of this study were to i) develop, apply, and compare a chironomid-based index to SASS5 results in assessing water quality deterioration in selected urban riverine systems; ii) explore the distribution patterns of chironomid signature traits and ecological preferences in selected urban riverine systems; iii) develop a trait-based approach for predicting the resilience and vulnerability of chironomids to urban pollution, and iv) analyse the effect of multiple spatial filters on chironomid taxonomic and trait assemblage structure.

Three urban rivers (Bloukrans, Buffalo and Swartkops) were selected in this study. Macroinvertebrate samples were collected from selected sites in the different rivers using the SASS5 protocol, and transported to the laboratory for further processing. Chironomid species were sorted from the collected macroinvertebrate samples, mounted and identified to species morphotype level using identification keys such as Harrison (2004) and Wiederholm (1983). Important chironomid species traits in the assessment of urban pollution include the possession of haemoglobin, substrate attachment, and food preferences. The trait information of chironomid species was obtained from the South African macroinvertebrate trait database, laboratory observation, and literature.

One hundred and four (104) chironomid species were identified in the studied rivers. Indicator chironomid species for urban pollution monitoring were identified and a chironomid species-based tool developed using data from this study proved to effectively discriminate urban-impacted sites from least-impacted sites.

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

Student: M.M. Ralekhetla
Supervisors: C.G. Palmer, L. Kelland, and S.A. Paphitis
Degree: PhD (Water Resource Science)

Introduction and background

The management of complex social-ecological systems (CSESs) requires a transdisciplinary (TD) approach in order to integrate knowledge and methods from different disciplines to tackle the inherent complexity of the problems. The concept of participation plays a central role as the interface that fosters the interactions among the people who are involved in a CSES. Participation can be viewed through both instrumental and emancipatory approaches, depending on the underlying goals and motivations. Power dynamics and epistemic injustice play significant roles in shaping the differences between instrumental and emancipatory approaches to participation in various contexts, including decision-making processes.

In this study, some participants who took part in the Tsitsa Project (hereafter 'TP'), a restoration project in the Eastern Cape, South Africa, were asked to narrate their stories of participation, both from before the TP and their experiences participating in the TP. I used case study narrative inquiry and poetic inquiry, since they all emphasise and uncover participants' subjective experiences, meanings, and interpretations.

Findings

Knowledge of context came up as an important enabling factor for conducting participatory processes. Recognising and respecting context and diversity among those involved in a participatory process was also mentioned as a prerequisite for learning, which in turn, helped the participants to gain confidence on the one hand, and enabled them to adapt to different participatory spaces on the other. Diversity also came up in its role in enabling human connection, which led to the ability to adapt and to find a place in the different participatory platforms. Finding a place or a role in the participatory space led to recognition of their contribution to the space, which in turn boosted their confidence to participate (Figure 1).

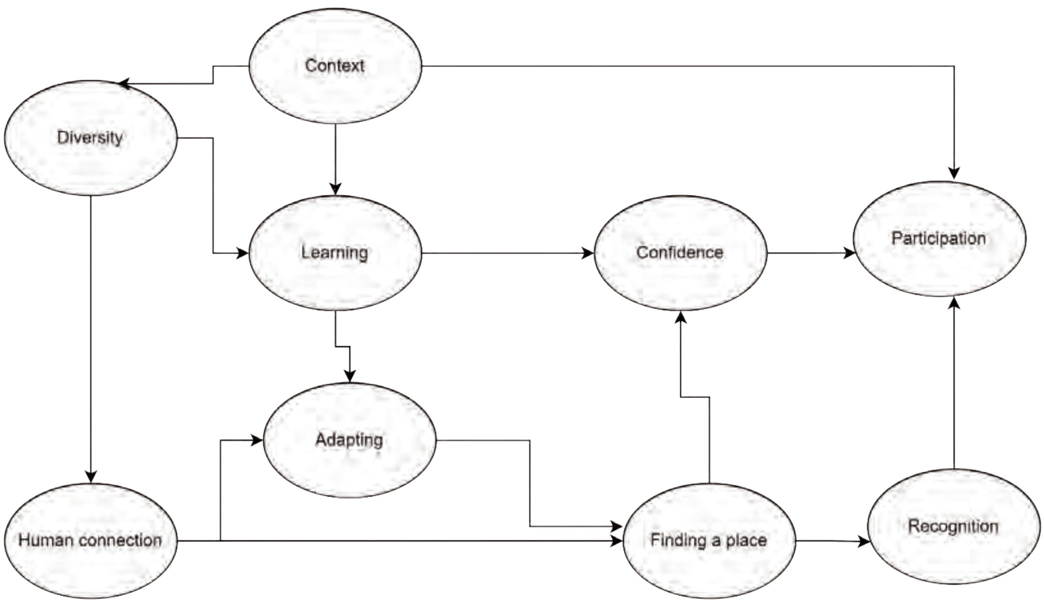


Figure 1: A representation of some of the highly occurring themes across the different stakeholder groupings indicating the factors that influenced participation in the different activities mentioned in participant narratives.

Through the words of the participants, I have been able to surface the meaning attached to participation and discovered that the heart of meaningful participation is embedded in epistemic justice. Designing and practising participation must be done with a conscious recognition of epistemic justice, and should be done in a manner that enables emancipatory participation. Use instrumental participation cautiously to avoid being oppressive and exclusionary.

Simulating groundwater recharge under climate change in the Twee River catchment, South Africa

Student: N.L. Dlamini
Supervisor: D. Gwapedza
Degree: BScH (Geography)

According to the Department of Environmental Affairs (2016), in South Africa, "Water is the primary medium through which the impacts of climate change are being felt". These impacts include intensifying extreme rainfall events that lead to flooding, and extreme and prolonged droughts that increase the risk of wildfires. Immediate planning and action are required to mitigate these threats, especially the mitigation of droughts in southern Africa.

Assessing future groundwater recharge under climate change is essential to prevent groundwater resources from completely drying up in the future. There are substantial agricultural, domestic, ecosystem, industrial and municipal demands and water uses for groundwater; the drying up of groundwater would have devastating implications for these sectors in the future, as highlighted by the water-food-energy-climate nexus.

This desktop-based study assessed future groundwater resources under climate change Representative Concentration Pathway (RCP) 4.5 and RCP 8.5 using a SWAT model simulation in the Twee River catchment, South Africa. This assessment aimed to evaluate quantitatively how groundwater recharge would change under moderate and high carbon emission scenarios.

The research objectives were to i) process projected climate data for input into the SWAT model; ii) simulate groundwater/recharge scenarios using the SWAT model; iii) evaluate how projected climate scenarios would impact groundwater recharge.

Climate data from the Canadian Centre for Climate Modelling and Analysis, the Swedish Meteorological and Hydrological Institute, and the Royal Netherlands Meteorological Institute were prepared and processed. The data were downscaled to weather stations in the catchment and bias-corrected against the historical climate in the catchment. The corrected data underwent processing for climate inputs into the SWAT model, and a simulation was completed.

Findings indicated that projected precipitation would decline and projected temperatures would increase, resulting in a projected decline under both scenarios. The RCP 8.5 produced the most significant recharge decline.

Tables 1, 2, and 3 present the central tendencies of the climate variables, precipitation and temperature in the historical RCP 4.5 and RCP 8.5 climates, respectively. The general trend of the data suggests that future mean precipitation will decline when comparing the scenarios to each other (RCP 4.5 and RCP 8.5) and relative to the baseline. Projected mean temperatures will increase when using the same comparison. The decline in projected precipitation and increase in projected temperatures results in a projected groundwater decline, as illustrated in the baseline versus future mean monthly recharge (Table 4), the annual projected recharge (Figure 1), and the flow duration curve illustrating baseline and future recharge (Figure 2).

Table 1: *Measures of central tendency for the historical climate in the Twee River catchment.*

Historical Climate	Max	Mean	Median	Mode
Precipitation (mm)	106.83	1.89	0	0
Temperature (°C)	30	13.69	14.55	14.05

Table 2: Measures of central tendency for the simulated climate for the low carbon emission scenario 4.5.

RCP 4.5	Max	Mean	Median	Mode
Precipitation (mm)	139.46	1.55	0	0
Temperature (°C)	32.31	14.39	13.97	13.17

Table 3: Measures of central tendency for the simulated climate for the high carbon emission scenario 8.5.

RCP 8.5	Max	Mean	Median	Mode
Precipitation (mm)	116.01	1.49	0	0
Temperature (°C)	32.20	14.71	14.37	10.13

Table 4: Mean monthly recharge for the Twee River catchment.

	Historical	RCP 4.5	RCP 8.5
Mean monthly recharge (mm/a)	0.30	0.23	0.21

Sediment dynamics in meandering floodplain wetlands in the Tsitsa River catchment: implications for floodplain systems in southern Africa

Student: P. Huchzermeyer (Schlegel)
Supervisors: B. van der Waal, S.E. Grenfell, and J.L. Tanner
Degree: PhD (Geography)

Although a large body of international knowledge and literature has advanced our understanding of river-floodplain systems, many knowledge gaps exist for dryland systems. Floodplain systems reflect complex and dynamic interactions between processes and patterns. Understanding how processes generate observed patterns and, in turn, how patterns influence processes is critical to understanding floodplain structure and function and requires an interdisciplinary approach in both research and resultant applications. This thesis examines the sediment and associated total phosphorus dynamics, and the storage within two contrasting floodplain systems in the temperate environment of the upper Tsitsa River catchment, South Africa.

River systems are dynamic landscape components that play essential roles in ecosystem processes. Although rivers transport sediment and sediment-associated nutrients and toxins to the oceans, they also store sediment, nutrients, and contaminants along floodplains. Floodplains can serve as long-term storage (>10^2 years) and, as such, floodplain systems play a significant role in the catchment's sediment and nutrient budget. Wetland systems' ability to provide ecosystem services, like sediment trapping and nutrient assimilation, depends on their geomorphic structure, hydrological regime, and topographic placement within the landscape.The following specific objectives were set for the research:

- Estimate and describe the sediment and phosphorus flux and potential erosion from the two channels.
- Investigate the spatial variability of the sediment and phosphorus composition of recently deposited sediment on the floodplain surfaces, exploring the relationships and patterns between the sediment characteristics and the geomorphology of the two floodplain systems.
- Quantify and characterise the historical sedimentation and phosphorus storage rates, the trapping efficiencies, and the effect that geomorphology has on these values within the two floodplain systems.
- Evaluate the two meandering floodplain systems regarding ecosystem service (sediment trapping and phosphorus assimilation) delivery.
- Investigate the effectiveness of local and catchment controls on the floodplain systems' sediment trapping.

I am in the final stages of my PhD, writing and compiling my research into a thesis.

Assessment of Pitman Model capabilities in modelling surface water-groundwater interactions in the Lake Sibaya catchment, South Africa

Student: P. Ramatsabana
Supervisors: J.L. Tanner and S.K. Mantel
Degree: MSc (Hydrology)

This research aimed, firstly, to determine the feasibility and utility of applying the conceptual-based modified Pitman model, which is extensively used nationally for surface water (SW) purposes and, less commonly, for estimating groundwater (GW) processes and surface water-groundwater interactions. The model was assessed on how accurately simulated water balance variables reflected available evidence and expected catchment response. Secondly, the study identified and addressed uncertainties surrounding the structure and application of the model's groundwater interaction components. The model was set up and calibrated for the Lake Sibaya catchment, which is a primarily groundwater-driven environment.

This case study was not a typical application of the Pitman modelling tool from a scale perspective, nor from a groundwater perspective. The work assessed the limits of the Pitman model in adding value to groundwater-focused modelling exercises, recognising that the conceptual model will never replace a numerical groundwater model, but that, in light of the data and time intensity of running a numerical model, the Pitman model could add value by exploring a system's major water balance components prior to more detailed water balance modelling. A timeseries of the major water balance components and the data analysis options in the model could be helpful for a first-stage investigation.

The study arrived at the following key findings:

- Lake Sibaya's volume fluctuates in response to varying inputs (rainfall, surface runoff and groundwater outflow into the lake) and outputs (evaporation from the lake surface, lake outflow and abstractions).
- Groundwater inflow simulations support previous findings that show GW largely sustains the lake.
- Overall decline observed in lake volumes is largely due to climate change (Figure 1).
- The lake volume decreases with increasing development (forestry and abstractions) in the lake catchment.
- The presence of forestry in the lake catchment (Figure 2) reduces the volume of baseflow moving into the rivers.
- Rainfall uncertainty in the study area is significant.
- The updated GW and SW-GW interaction components of the model were able to model the GW-driven environment of the Lake Sibaya catchment satisfactorily.

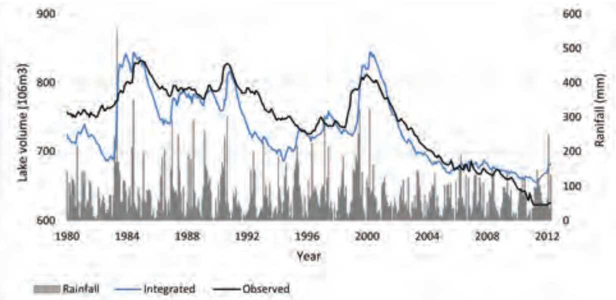


Figure 1: Lake volume for integrated simulation vs observed data (observed lake level was converted to a volume using bathymetric information, to compare directly to model-simulated lake volume)

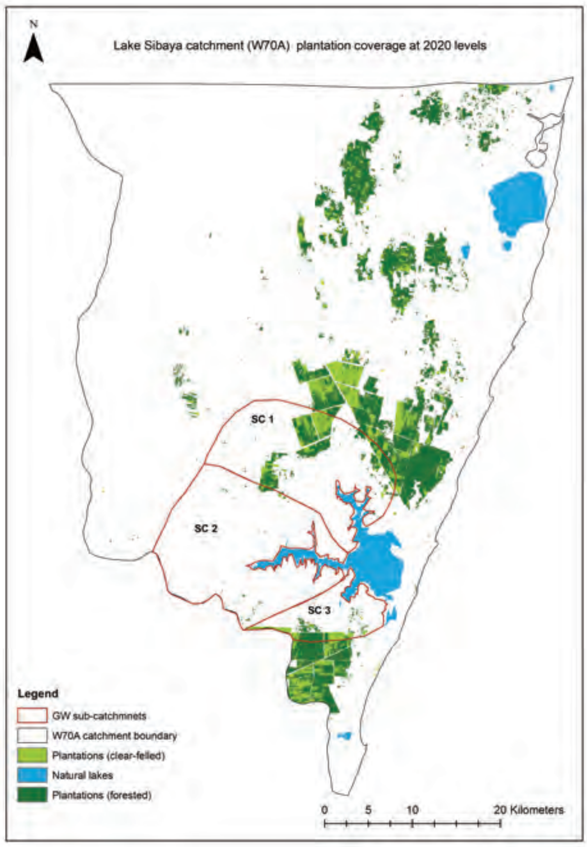


Figure 2: Plantation coverage in the Lake Sibaya catchment at 2020 levels (South African National Land-Cover (SANLC), 2020).

The model performed satisfactorily in simulating the lake's water balance correctly enough such that the influences of dominating components were sensibly reflected in variations in streamflow and lake volumes.

After graduating in October 2023, I continue to support the IWR in other initiatives, including the ongoing development of a comprehensive water management plan for the University to address water insecurity concerns on campus. My responsibilities include creating detailed maps of the University's water infrastructure and reticulation system, alongside estimating water demand for key usage categories.

I am also actively involved in planning the ARUA Water Centre of Excellence workshop for the 2023 ARUA Biennial Conference. The workshop aims to explore the academic journey, reflecting on individual and collective milestones and challenges, while identifying pathways for enhancing the quality and quantity of outputs from African higher education institutions. Both initiatives offer exceptional opportunities for personal and professional growth, allowing me to cultivate proficiency in engaged research methodologies.

Applying the Modified Pitman and SWAT models to estimate groundwater recharge in the upstream area of the Uitenhage Artesian Basin, South Africa

Student: P. Wasswa
Supervisor: J.L. Tanner
Degree: MSc (Hydrology)

Introduction

The Uitenhage Artesian Basin (UAB) (Figure 1) is an important groundwater artesian basin in South Africa where water abstraction through boreholes in the basin has resulted in lowered artesian pressure. Addressing these problems, common to artesian basins globally, requires a holistic approach to estimating groundwater recharge. Although the UAB has been locally well-researched in terms of hydrogeological characteristics, knowledge of the upstream groundwater recharge dynamics of the basin is insufficient. The upstream area consists of Table Mountain Group (TMG) rock known for high recharge volumes and deep groundwater flows owing to its highly folded and fractured nature.

To understand the recharge dynamics of a particular area, scholars and scientists recommend applying a variety of methods, of which hydrological models are one. However, selecting suitable hydrological modelling tools for use in groundwater recharge estimation remains a challenge. The current study aimed to explore and address this issue by applying holistic approaches to understanding groundwater recharge dynamics using knowledge from previous research in the area, in combination with the application of the modified Pitman and SWAT models.

Research aim and specific objectives

The overall study objective was to evaluate the application of the Modified Pitman model and Soil Water Assessment Tool (SWAT) model to estimate groundwater recharge in the upstream area of Uitenhage Artesian Basin and was achieved using the following specific objectives:

1. To design a conceptual-perceptual model to be used in understanding groundwater recharge dynamics and setting up the numerical hydrological models in upstream area.
2. To estimate groundwater recharge using all available data, together with the Modified Pitman and SWAT models in the upstream area.
3. To compare the outputs of the two numerical models with one another and to local studies.

Methodology

First, the study developed a conceptual-perceptual model to build a better picture of the upstream area recharge dynamics.

Results

1. The area is dominated by irregularly folded and fractured TMG (Nardouw and Peninsula) rock outcrops which form secondary aquifers with groundwater flow paths in the Nardouw, being perpendicular to the cross-section and controlled by the fault system (Figure 3). The Bokkeveld group (aquitard) lies in syncline section with shale-bearing rocks that infill the Elands River valley, providing substantial lateral recharge both through surface-channel

seepage and surface percolation.

2. The SWAT model (Figure 5) represented declining groundwater recharge over the simulation period (1993–2021), while the Pitman-modelled groundwater recharge (Figure 4) exhibited an insignificantly decreasing trend throughout the study period.
3. Both models clearly captured low recharge values expected in drought events that were reported in literature (i.e., 2007/2008; 2015/2016; 2016/2017 and 2018/ 2019)

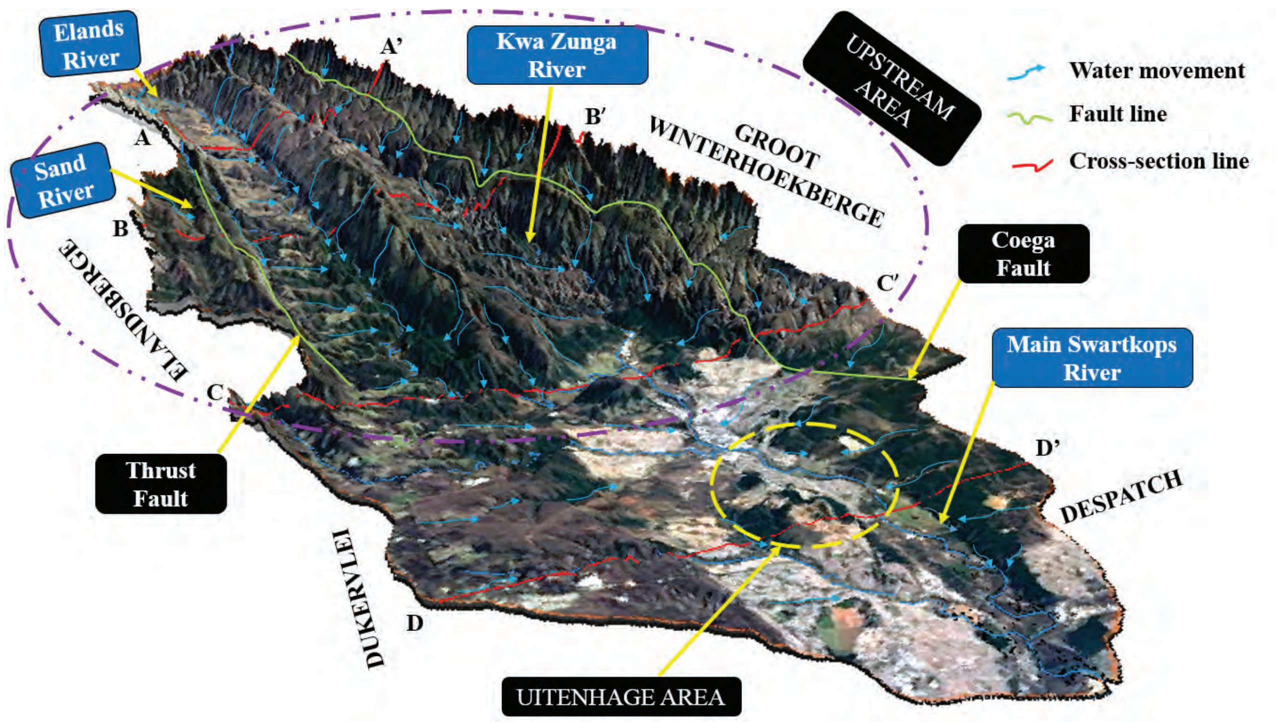


Figure 1. 3D topographic map of UAB showing superimposed water movement and cross section lines.

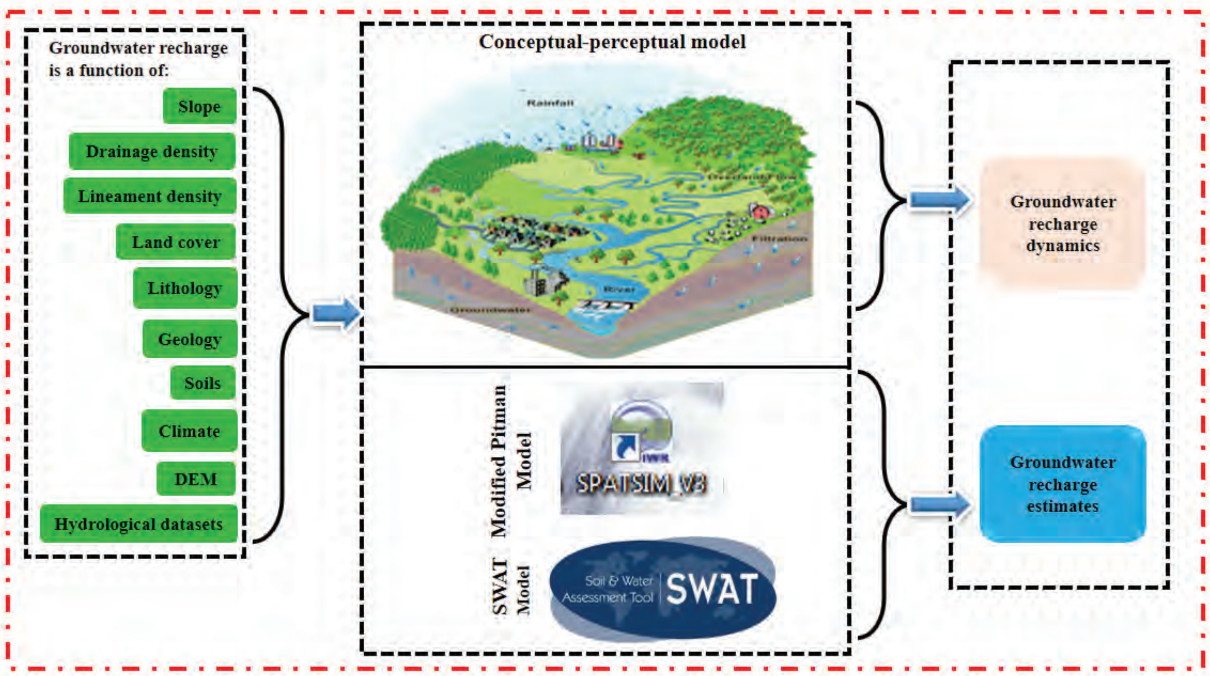


Figure 2. Methodological flow diagram

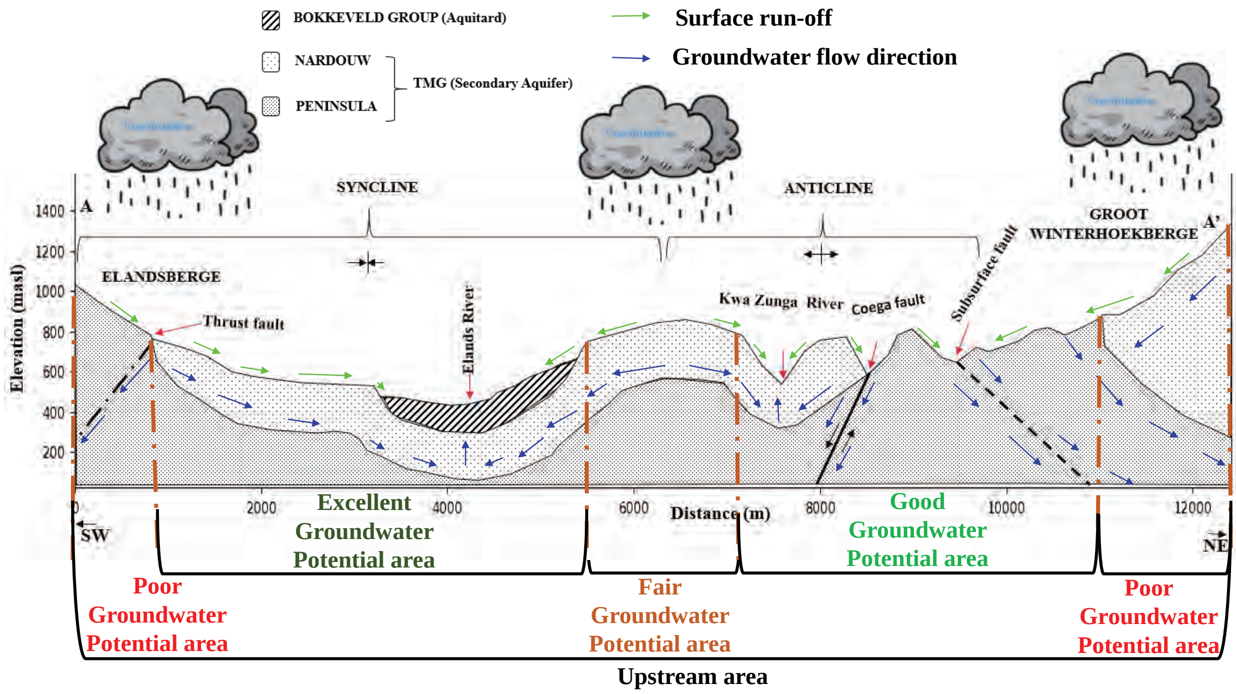


Figure 3. Cross-section showing developed conceptual-perceptual model illustrating groundwater recharge flow dynamics in the upstream area.

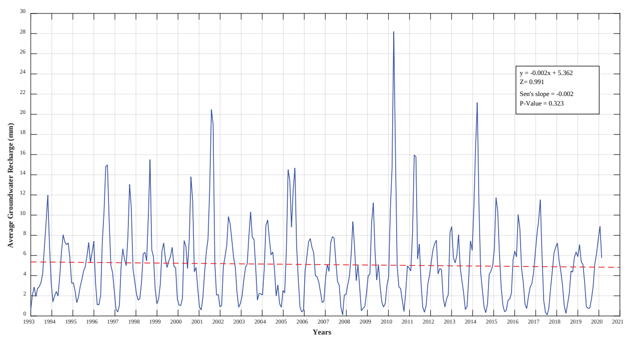


Figure 4. Pitman hydrography of estimated groundwater recharge

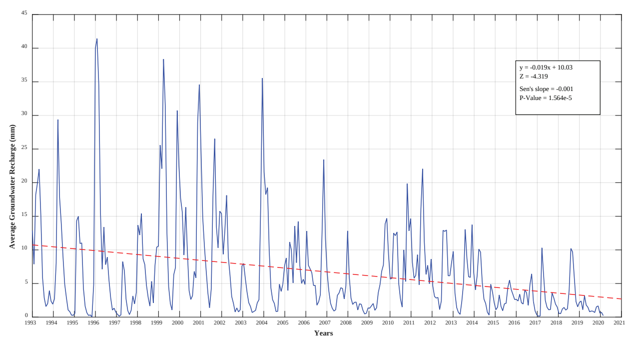


Figure 5. SWAT hydrography of estimated groundwater recharge

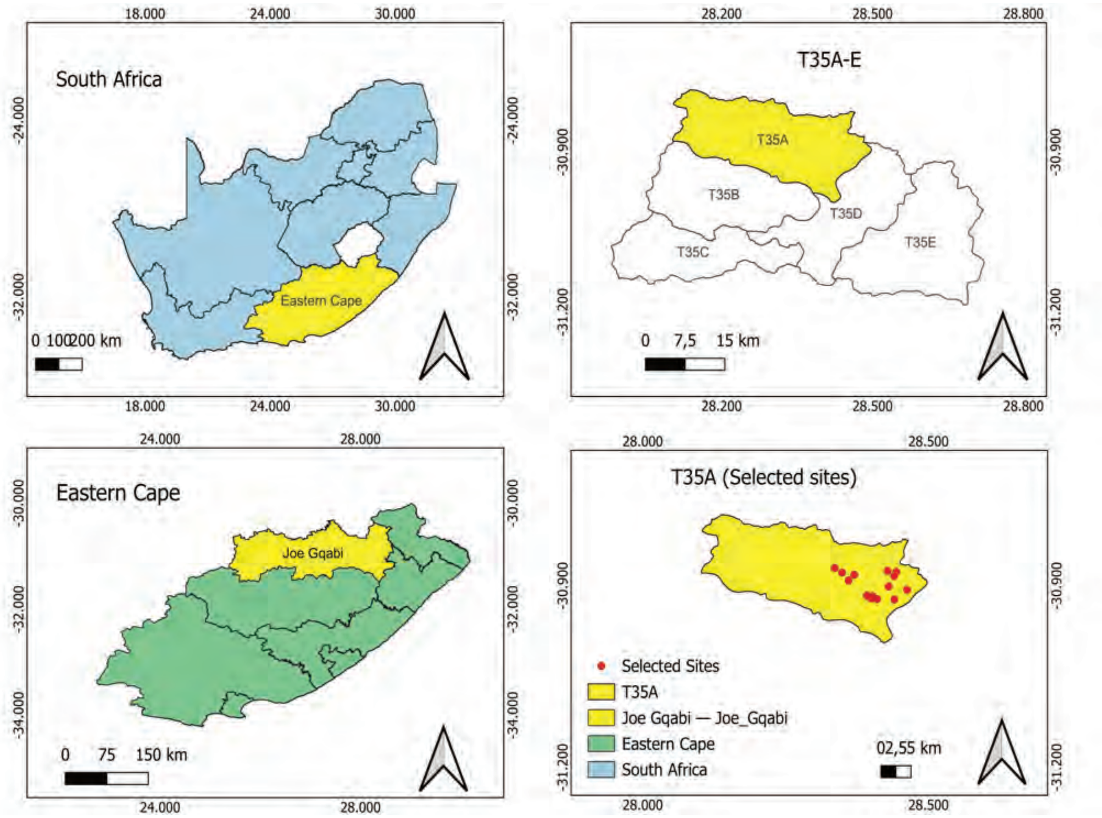
Conclusion

Both Pitman and SWAT models predicted decreasing rates of groundwater recharge in the upstream area over time, though they did predict average amounts and interannual patterns of recharge, surface runoff, and other water balance components with differing peaks, low values and timings due to the different data input model structure. In reference to earlier findings within TMG areas, estimated percentages of groundwater recharge were close to those simulated by both Pitman and SWAT models and thus the application of the two models to estimate groundwater recharge in the upstream area of UAB was satisfactory. The differences in the two model outputs, however, highlighted the uncertainty in the simulations, which could not be resolved, given the data scarcity of recharge information.

An assessment of abandoned cultivated lands: a case study of Lower Tsitsana and Hlankomo in the Tsitsa River Catchment.

Student: R.N. Dakie
Supervisors: A. De Vos, S.K. Mantel, and B. Gusha
Degree: MSc (Environmental Science)

Agriculture is an essential part of life's economic and social aspects, with many people living in rural and urban areas dependent on it for income generation and food production. However, agricultural activities are declining worldwide, as is seen through an increase in cultivated land abandonment. Cultivated land abandonment can be defined as the intentional or unintentional cessation of agricultural activities for other land uses, such as forestry, wildlife development, and recreational purposes. The United Nations Food and Agriculture Organisation (FAO) defines land abandonment as the cessation of farming and giving away land for nature without signs of management for at least four years. This phenomenon is complex and operates at varying spatial and temporal scales, and it is characterised by various ecological and socio-economic drivers. The ecological drivers may be climate-related factors, such as rainfall variability (droughts and floods), soil fertility and erosion, and the slope and aspect. The socio-economic factors may include industrialisation, migration and rural depopulation, land tenure systems and changing government regimes.



Study area map showing the T35A-E quaternary catchment.

Aim

This project aims to identify abandoned cultivated land in the Lower Tsitsana and Hlankomo rural areas of the Tsitsa River catchment and understand its history and changes over time to identify sustainable management practices that can support local livelihoods.

Research question

How can abandoned cultivated lands be managed to promote sustainable management of the landscape in the Lower Tsitsana and Hlankomo rural areas of the Tsitsa River catchment?

Study area

The study was conducted in two villages under traditional leadership, the Hlankomo and Lower Tsitsana traditional areas in the Tsitsa River catchment in the Joe Gqabi District Municipality of the Eastern Cape Province, and covered sixteen sites divided between two villages.

Progress

The study assessed the ecological conditions of the abandoned lands and conducted interviews with the local people in the two villages. The ecological conditions were assessed using grass species composition, while the interviews were conducted to understand the drivers of change and explore the future perspectives of the abandoned lands. The abandoned lands are dominated by Increaser II grass species, which grows in deteriorated veld conditions. The interviews showed that many people in the catchment are still very interested in recultivating the abandoned lands, that they are not happy with the current condition of the lands and would prefer to re-use them for cultivation again. However, the critical question is whether the lands would be able to support their needs in their current condition as the grass species assessment indicated that the fields are degraded.

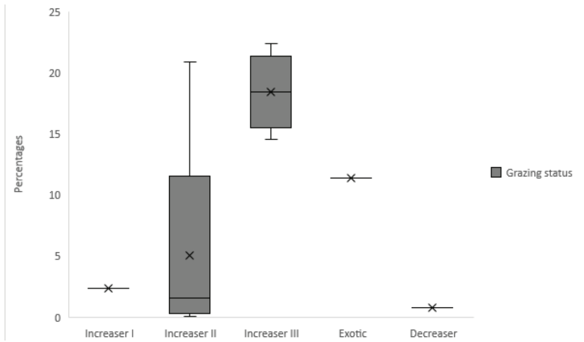


Figure 2: The abundance values for the different grass grazing status. The box and whisker plot shows that increaser III species were the most dominant grass species, while Decreaser species were the least appearing In Hlankomo and Lower Tsitsana

Agent-based modelling as a stakeholder-driven process towards equitable water use and sustainable catchment management in the Koue Bokkeveld

Student: R.S. Tholanah
Supervisor: K. Bradshaw and S.K. Mantel
Degree: MSc (Computer Science)

Water is an essential natural resource, with multiple industrial and domestic uses. South Africa has a water scarcity problem, with population growth due to increase the demand for industrial and domestic water, thus exacerbating the problem. In 1998, the South African government promulgated the South African National Water Act (Act 36 of 1998), which provided guidelines on the equitable sharing of water resources. The Act stipulated measures to protect aquatic ecosystems by instituting the Ecological Water Requirements (EWR) which specified the minimum amount of water required in river systems to be functional and sustainable. However, the EWRs are not being met, given the water scarcity problem. Competition for the limited water resources also results in conflicts, in which little consideration is given to the EWRs. One of the regions in South Africa affected by the water scarcity problem is the Koue Bokkeveld (KBV) region, an agricultural area in the Western Cape of South Africa. This project is part of the WRC Project # C2020/2021-00607.

Problem statement

Water scarcity has increased competition among users, straining the river systems. Computer modelling could be used to find solutions to the sustainable sharing of limited water resources among the KBV stakeholders. This project used agent-based modelling (ABM) to carry out simulations to co-create an effective water management strategy with the stakeholders in the KBV region to use the limited water resources sustainably. The project aimed to model the current situation and simulate future scenarios based on climate variability projection and other potential changes.

Objectives of the research

The sub-objectives of this research are to:

- develop a generalisable ABM for the KBV region through collaboration with the farmers and other stakeholders in the KBV region;
- contribute to a water management strategy;
- investigate how climate variability affects water availability and create strategies that farmers could use to combat problems caused by climate variability.

Project progress

A workshop was held in November 2022 where a conceptual model of the ABM was validated. A presentation was given to the stakeholders explaining the various input data the model would require. The presentation also showed how the model would work through several hypothetical scenarios. At the end of the workshop, the participants were given questionnaires regarding how the farmers made use of water.

The survey results were used in developing the ABM. Verification of the ABM was performed by comparing SWAT flows (SWAT provides the input hydrological data) with those from the ABM and checking the ABM's water balance. Validation was performed by consulting with catchment experts and by using survey data.

The model is being used to explore various future scenarios, such as:

- Moderate and extreme climate change.
- Increase in hectarage of cultivated crops.
- Addition of a shared dam controlled by a WUA agent for downstream farms. In this scenario, the dam capacities of upstream farms are increased, and downstream farms make water requests to the WUA for water. The WUA also releases water each week to maintain EWR flows.
- Release of water by farms with large dams during summer.
- Increase in dam capacities.

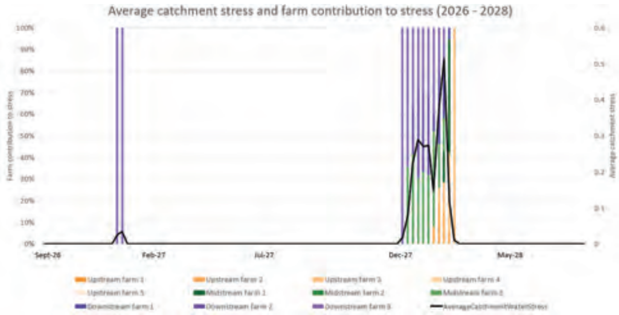


Figure 1: Graph showing farm water shortages for the moderate climate change scenario. Stress is an indicator of water availability with 0 meaning there is enough water and 1 meaning there is no water.

Application of the Python water resources – Water Quality (Pywr-WQ) model: A case study in the Grootdraai Dam Catchment, Upper Vaal, South Africa.

Student: S. Lazar
Supervisors: N. Griffin, F. Akamagwuna, and A.R. Slaughter
Degree: MSc (Water Resources Science)

Supporting diverse industries, the Grootdraai Dam catchment is crucial for South Africa's economic growth. However, changes in land use and climate affect water quality, impacting ecological health and sustainability. This research focuses on developing tools for sustainable water quality management in the Grootdraai Dam catchment. It employs the Python water resources-Water Quality (Pywr-WQ) model that closely mirrors the water system topology and is dynamically linked to the Python water resources (Pywr) model. This study simulated variations in water quality, taking into consideration evolving climate conditions and alterations in land cover within the study area. Predictive land cover models were developed to estimate non-point nutrient and salt inputs into the Grootdraai Dam catchment. These models, built using a multiple regression analysis method, served as essential input parameters for the Pywr-WQ model, and the regression models were validated against a calibrated Pywr-WQ model.

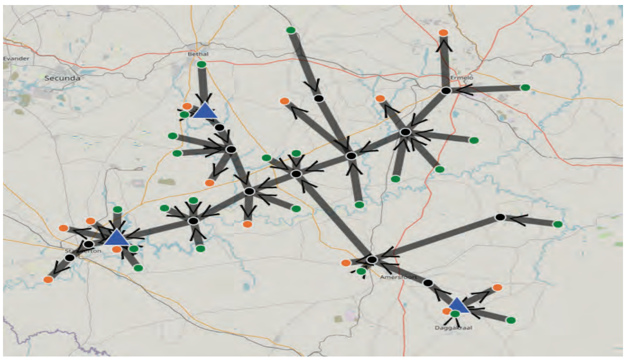


Figure. 1: Pywr model for the Grootdraai Catchment implemented in the online version of Pywr (www.waterstrategy.org)

Climate change simulations indicated that several water quality variables exhibited minimal deviations from the baseline scenario, among them chlorine, nitrate, phosphate, magnesium, sulphate, calcium, and ammonium. Conversely, some variables, such as fluorine, sodium, potassium, and total dissolved solids displayed slightly elevated concentrations in comparison to the baseline scenario.

Under historical climate conditions, an average increase of 0.015% in mining land cover was simulated through a combination of the Pywr-WQ and multiple regression models. Notably, total dissolved dolids and sulfate levels in various sub-catchments consistently exceeded the generic Resource Quality Objectives (RQOs). Over the long term, some sub-catchments experienced frequent and prolonged deviations beyond the RQO limits. Figure 2 shows the percentage compliance of water quality with total dissolved solids and sulphate RQOs in one of the highly impacted quaternary catchments within the study area.

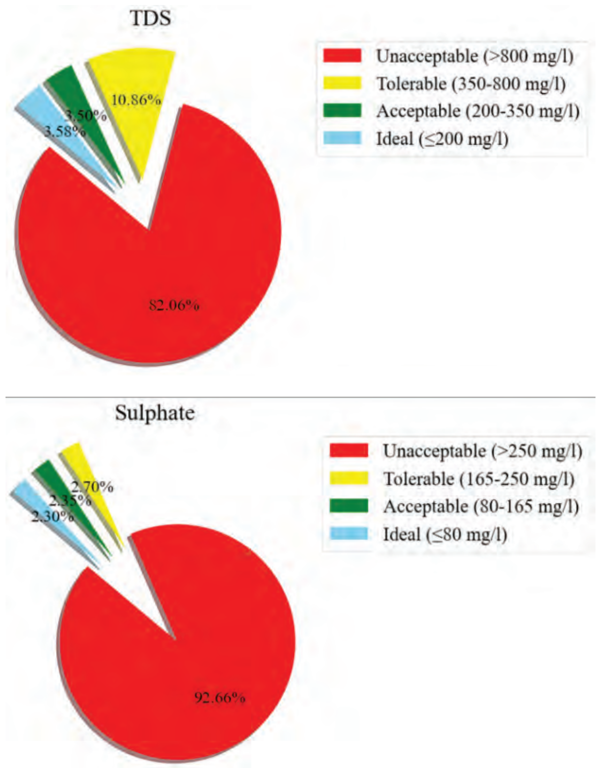


Figure. 2: Percentage water quality compliance with total dissolved solids and sulphate RQOs in the highly impacted quaternary catchment C11B by mining activities within the Grootdraai Dam catchment, Upper Vaal, South Africa, for long-term simulations.

Simulations were also carried out to evaluate nutrient concentrations in the cultivated land scenario, featuring an average increase of 0.3% in cultivated areas within the Grootdraai Dam catchment. The findings underscore a significant concern related to non-point agricultural nutrient pollution and its pronounced impact on the water quality of Grootdraai Dam. The expansion of cultivated land cover is associated with elevated nitrate and ammonium levels in the medium and long term, compared to other land-cover scenarios. The surplus introduction of inorganic nitrogen into the aquatic environment through agricultural activities can potentially foster the development of algal blooms, with implications for human and ecosystems health.

Examination of the urban land-cover scenario provided valuable revelations about phosphate levels in the Grootdraai Dam catchment. Despite a minor increase of 0.05% in urban land cover, phosphate concentrations consistently surpass the recommended RQO thresholds,Top of FormBottom of Form presenting clear evidence of probable non-point sources that may led to increase in phosphate levels, such as leakage in wastewater treatment pipes, sewage, and other sources.

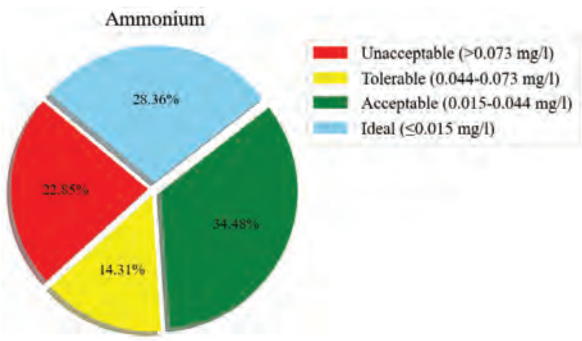


Figure. 3: Percentage compliance of water quality with ammonium RQOs at the Grootdraai Dam, Upper Vaal, South Africa for long-term simulations.

Application of SWAT+ hydrological model to assess the water balance of irrigated agricultural catchments in the Western Cape, South Africa

Student: S. Mabohlo
Supervisors: J.L. Tanner and D. Gwapedza
Degree: MSc (Hydrology)

South Africa has limited water resources due to low and erratic rainfall. Even though the country is water-stressed, the National Development Plan (vision for 2030) advocates for expanding irrigated agriculture (which is already consuming 63% of available water) by 50%. Expanding irrigation agriculture is expected to be achieved through increasing water use efficiency. However, relying solely on increased efficiency is unrealistic, not only because irrigation expansion demands increased water supply, but also because of droughts and poor management of this resource. Increased demand for irrigation water and the impacts of droughts accompanied by poor water management have exacerbated conflict among farmers and led to overexploitation of water resources. These issues often mean that other water-user groups, such as domestic, industrial and the environment, do not get the required supply as outlined in the National Water Act.

Sustainable water management planning has been identified as a key strategy that can be implemented with efficiency to ensure the success of irrigation expansion without conflict or jeopardising the availability of water for other uses. Such planning is also considered critical for ensuring the sustainability of available water in the context of the droughts that the country has recently experienced. A sustainable water management plan requires a quantitative understanding of water balance components, and hydrological models remain essential tools to quantify catchment water balance components at various scales.

This study applied the SWAT+ model to quantify the water balance of the Twee and Leeu River catchments to support the development of a sustainable water resource management and utilisation plan for the study area. The specific objectives are to:

1. Set up and evaluate SWAT+ model performance in simulating water balance for the Twee and Leeu River catchments, Western Cape, where there are significant abstractions for irrigation purposes;
2. Assess the need for a physically based, daily hydrological model in an environment where precision water management is occurring, considering the high data and time cost.

The model simulated the catchments' hydrological processes satisfactorily with good statistical values of Nash-Sutcliffe Efficiency (NSE), 0.76 for Twee and 0.68 for Leeu, after calibration (Figure 1). The model output shows that high runoff (water yield) is generated between May and September due to high rainfall during this winter period (Figure 2). There is little rainfall during the growing season (October to April), meaning that a significant amount of irrigation water from winter runoff captured and stored in reservoirs is used to compensate for the insufficient rainfall. Approximately 90% of irrigation water and little rain in the growing season is converted into ET, making it the largest water balance component. SWAT+ accurately presented the temporal variability of the catchments' hydrological processes and irrigation requirements. The model also demonstrated that irrigation demands are met using runoff stored in reservoirs. Based on model results, additional dams could be essential to capture and store more of the high runoff generated during the wet period to ensure water availability for irrigation during the dry season.

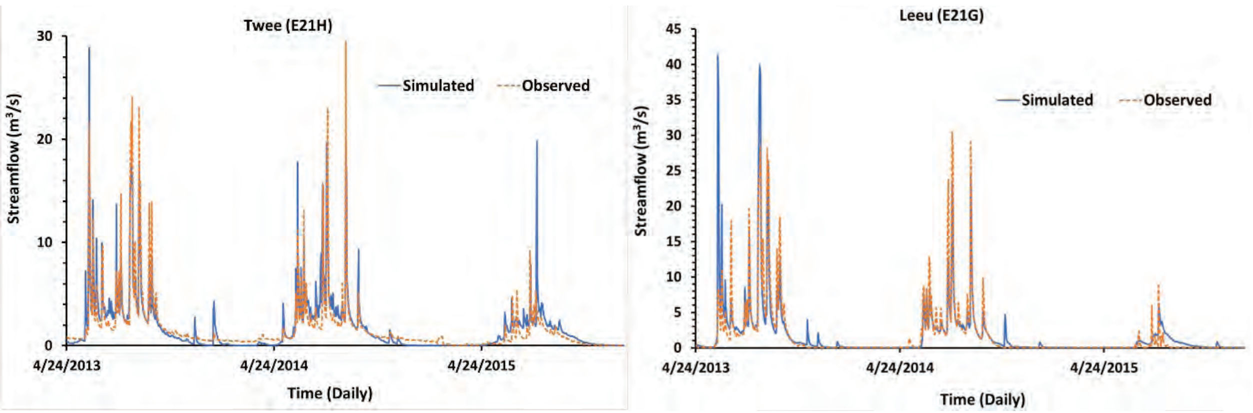


Figure 1: Hydrographs of model calibration.

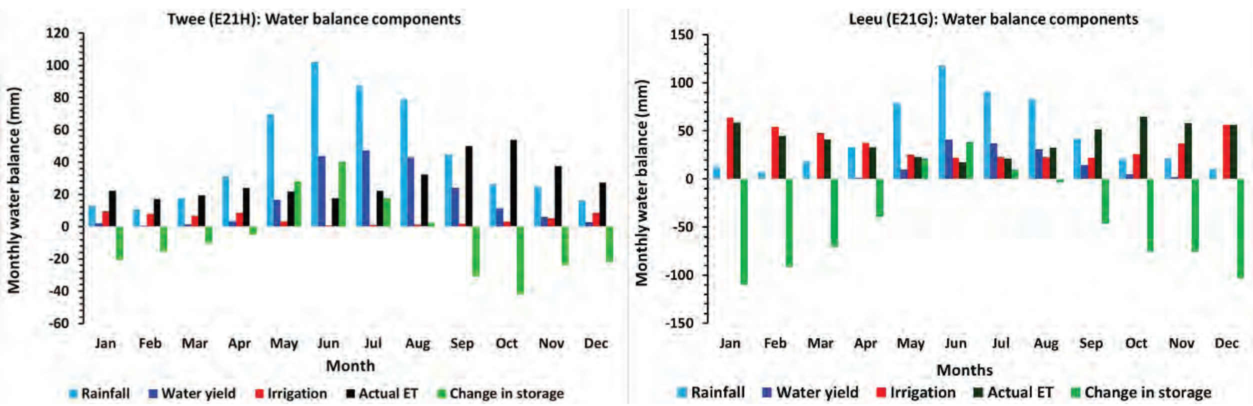


Figure 2: Mean monthly water balance components from 1995 – 2020.

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

Student: B.S. Xoxo
Supervisors: J.L. Tanner, S.K. Mantel, and D. Hughes
Degree: PhD (Hydrology)

The PhD project

I am completing the development of a water-use model that incorporates uncertainty and involves water consumers as part of a WRC Project that focuses on water management in the Koue Bokkeveld region, Doring Catchment, Western Cape. The model is designed to analyse human-water system risks, helping to negotiate water consumption decisions during dry spells, while reducing risk from water supply limitations and environmental consequences.

I adopted the coupled human-water system approach to better investigate the existing and emerging co-evolutionary dynamics between the two systems and constructed a socio-economic data-gathering procedure using a role-playing game to facilitate model communication while assessing the viability of the suggested water-sharing solutions. Collaborating stakeholders include water consumers, environmental protection professionals, and extension service officers who assessed the model's applicability in decision-making.

The model provides a holistic picture of the water-use situation in dry periods with uncertainty to ensure the risks of decisions are understood. The model also provides options for allocating water according to impact, that is, the impact of a water deficit on a particular user. This way, users with little protection against water cuts are prioritised for supply, making the tool essential for fair and efficient use of water.

Since 2017, the agricultural sector in the Western Cape has been exposed to restrictions ranging from 50-87%. This approach emphasises South Africa's dedication to equity and sustainable development and asks how water restrictions can be better apportioned to ensure that the impacts are fairly distributed across users while safeguarding the environment and society. Figure 1 depicts the impact curves quantifying the users' vulnerability to reduced allocation. The model considers both consequences and constraints to suggest a policy that the stakeholders may agree on and include in their long-term strategic water planning, so increasing preparedness for dry spells, reducing water conflicts, and achieving fair and sustainable water use.

Sinetemba Xoxo (green shirt) facilitating the role playing game as the Water Users' Association chairman in the Twee wyk.

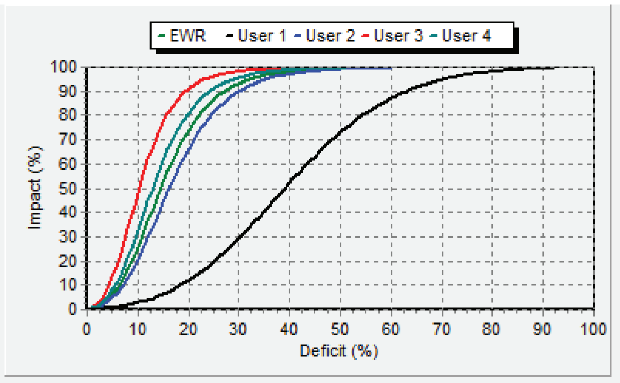


Figure 1: Output 1 of the water-sharing model, showing inequal vulnerability of water-user groups in the Twee wyk. The EWR represents environmental use, User 1 represents cooperate farms, User 2 is family farms, User 3 are downstream farmers, and User 4 denotes hedonic users. Socio-economic vulnerability is assessed based on individual capacity to cope with dry spells because of operational, tactical or strategic arrangements.

The role-playing game which assists in gathering information was developed with Dr Olivier Barreteau and Dr Bruno Bonte of INRAE (National Research Institute for Agriculture, Food and Environment), in Montpellier, France. The several stakeholder groups (commercial family farmers, downstream farmers, government and non-government practitioners) who played various roles as water users, water managers, or observers learned important lessons about collaborative management, environmental protection during dry years, and they debated who would pay for environmental protection, and how to apply what we learned. The game is being modified for use in other, similar contexts.

As part of my research visits to Montpellier I attended the 9th International Conference on Decision Support System Technology and presented my research.

Research outputs

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