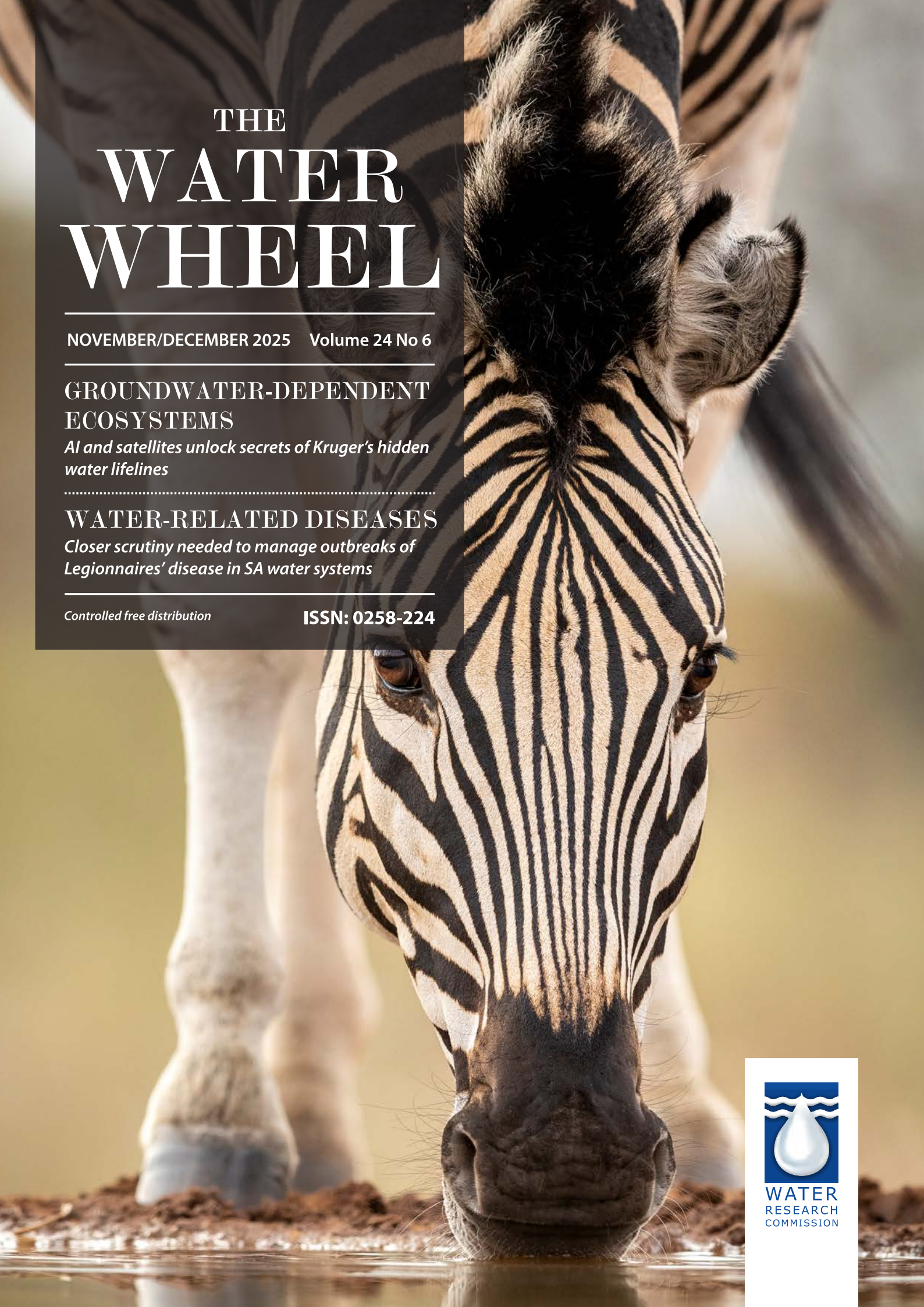


THE WATER WHEEL

NOVEMBER/DECEMBER 2025 Volume 24 No 6

GROUNDWATER-DEPENDENT ECOSYSTEMS

AI and satellites unlock secrets of Kruger's hidden water lifelines

WATER-RELATED DISEASES

Closer scrutiny needed to manage outbreaks of Legionnaires' disease in SA water systems

Controlled free distribution

ISSN: 0258-224

WATER RESEARCH COMMISSION

THE WATER WHEEL is a two-monthly magazine on water and water research published by the South African Water Research Commission (WRC), a statutory organisation established in 1971 by Act of Parliament. Subscription is free. Material in this publication does not necessarily reflect the considered opinions of the members of the WRC, and may be copied with acknowledgement of source.

Editorial Committee:
Prof Sylvester Mpandeli (Chair), Ms Manjusha Sunil, Mr Bonani Madikizela, Dr Mamohloding Tlhagale and Dr Sudhir Pillay.

Editorial offices:
Water Research Commission, Private Bag X03, Gezina, 0031, Republic of South Africa.
Tel (012) 761 9300.
WRC Internet address:
http://www.wrc.org.za
Follow us on X:
@WaterWheelmag
Editor: Lani van Vuuren,
E-mail: laniv@wrc.org.za;
Layout: Anja van der Merwe,
E-mail: anjavdm@wrc.org.za

Contents

04 **UPFRONT**

10 **GROUNDWATER-DEPENDENT ECOSYSTEMS**
AI and satellites unlock secrets of Kruger's hidden water lifelines

15 **INDIGENOUS CROPS**
Study sheds light on the mysteries of medicinal Pelargonium sidoides

18 **WATER-RELATED DISEASES**
Closer scrutiny needed to manage outbreaks of Legionnaires' disease in SA water systems

22 **INVASIVE ALIEN PLANTS**
Water vs wood: The high cost of alien trees in South Africa's catchments

26 **ESTUARIES**
From macro to micro: Tools for monitoring estuarine health and recovery

30 **GROUNDWATER**
Groundwater doesn't age like fine wine: Rethinking residence times in fractured rock aquifers

A recently completed study has combined remote sensing and machine learning to grow the body of knowledge around groundwater-dependent ecosystems of the Kruger National Park. See the article on page 10.

NEWS

Douglas Weir international heritage recognition celebrated

Water and Sanitation Minister, Pemmy Majodina, has encouraged communities and water stakeholders to use the global status of South Africa's irrigation structures as a springboard to improve their lives.

She was in the Northern Cape to hand over the World Heritage Irrigation Structure (WHIS) Award, bestowed on the Douglas Weir, located at the confluence of the Vaal and Orange rivers, to the Orange-Vaal Water Users Association (OVWUA), which manages the structure.

The Douglas Weir became the first South African irrigation structure to be awarded WHIS status by the International Committee of Irrigation and Drainage (ICID) in 2024. Only structures older than 100 years that have made a considerable contribution to the irrigation development of a country or region are considered for this award.

"There should be innovative structures that will bring an improvement to the supply of water and dignified sanitation to the local people and the surrounding areas. I call on the WRC and different stakeholders to make this site a hub for innovation for water and sanitation projects," Majodina said.

The WRC Board Chair, Dr Rethabile Melamu, reiterated the call. "We pledge to make this award a catalyst for economic development in the area and as a tool to relieve water and sanitation challenges. We will work with different stakeholders to ensure that this engineering marvel is used not only as an irrigation [structure], but as a boon to technological advances that will be used to change the lives of the people of Douglas."

In the picture can be seen: Prof Sylvester Mpandeli (WRC), Pemmy Majodina (DWS Minister), Dr Zamani Saul (Northern Cape Premier) and Peter Joseph (CEO of OVWUA) with the WHIS award.

South Africa's environmental department a driver of economic growth, not a barrier – minister

The Minister of Forestry, Fisheries and the Environment, Dr Dion George, has rejected the perception that the department acts as a brake on South Africa's economic progress. He said that such a view ignores the evidence that environmental policy is a generator of jobs and investment.

"Far from blocking growth, the Department of Forestry, Fisheries and the Environment (DFFE) is a catalyst for it. Our programmes show that sustainability is not a constraint, but the pathway to stronger competitiveness and inclusion," he said.

For years, critics have claimed that environmental regulations slow down industry, discourage investors, and cost South Africans jobs. The minister said that this narrative was both misleading and harmful because it hides the opportunities that come with a greener economy. He explained that global shifts since the 2008 financial crisis and the 2020 pandemic have already forced mining and industry to rethink their operations. The rise of climate-driven trade and investment patterns make it clear that carbon-intensive industries face growing risks, while cleaner and greener industries present major opportunities. South Africa's reality, he noted, is that the economy is dual in nature. Traditional, energy-heavy industries remain significant, while greener industries are emerging and fast becoming the foundation of future growth. Both need support, and both are linked to global market forces.

According to Dr George, the Climate Change Act of 2024 is a cornerstone of this dual approach. The Act, far from being red tape, creates the policy certainty investors need. It covers energy, transport, agriculture, forestry, biodiversity, waste, water and the built environment and positions South Africa for long-term competitiveness.

BACK TO TOP

Access to clear info on climate change impacts opens doors to better local level planning

In South Africa, there is clear statistical evidence of increases in 'warm extremes', such as heatwaves and high fire-danger days, over the last few decades. There is also some evidence of decreases in annual average precipitation across the region.

At the same time, the more frequent occurrence of extreme rainfall events has been detected across most of eastern and central South Africa. The devastating flooding in Durban in April 2022 and the severe southern African drought of the summer of 2023/24 are examples of extreme weather events made worse by climate change.

Their severe impacts were clear reminders of the need for anticipatory planning for climate change impacts. This planning should be based on credible and policy-relevant climate science.

Climate science is often not easily accessible, especially not in sufficient detail to inform adaptation responses at a sub-national and local level. The new sub-national climate change fact sheets, co-developed by the South African National Biodiversity Institute (SANBI) and University of the Witwatersrand Global Change Institute (WITS-GCI), aim to address this gap. They present an overview of observed historical and projected future changes in rainfall and temperature and their extremes, at provincial and district municipality level.

Through a process of distilling multiple lines of evidence of climate change in South Africa, they point towards actionable messages for adaptation at sub-national spatial scales. The fact sheets are intended to be a first foundational step in adaptation planning processes in South Africa. From this foundational step, it is anticipated that more detailed assessments, such as risk and vulnerability analyses, can be undertaken to enhance effective climate change risk reduction and adaptation, thus informing policy and supporting the implementation of the Climate Change Act (Act 22 of 2024).

To access the fact sheets, visit: https://zenodo.org/records/16962181

Limpopo university secures prestigious research chair to tackle water and climate challenges

The University of Venda (UNIVEN) has earned a major milestone in research excellence with the successful establishment of the DSTI/NRF-UUW-UNIVEN Research Chair in Water and the Environment, co-funded by the Department of Science, Technology and Innovation (DSTI), the National Research Foundation (NRF), and Umngeni-Uthukela Water (UUW).

Led by Prof Rachel Makungo, the Chair will focus on advancing knowledge and solutions "towards addressing water challenges in the water sector under changing climatic and environmental conditions." This Tier 2 Chair will run for an initial five-year period and is set to play a critical role in building research capacity. Over this period, it aims to support the development of at least eight Master's students, six PhDs, two postdoctoral fellows, and five emerging researchers.

The application underwent a rigorous peer-review process by an independent review panel comprising experts across multiple disciplines. Following conditional approval and successful revisions by Prof Makungo and UNIVEN, the Chair was officially recommended for funding, signalling confidence in the institution's ability to deliver impactful, sustainable research.

The NRF commended UNIVEN for securing this highly competitive Research Chair and emphasised the importance of institutional support in ensuring long-term success. This achievement reinforces UNIVEN's commitment to research that responds to national and global challenges, particularly in water security, climate resilience, and sustainable environmental management.

Responding to this achievement, the Executive Dean of the Faculty of Science, Engineering and Agriculture, Prof Natasha Potgieter, said, "Securing the SARChI Research Chair in Water and the Environment is a proud moment for our faculty and the entire University of Venda. It reflects the dedication and excellence of our researchers, led by Prof Makungo, in addressing one of the most pressing challenges of our time, water security under changing climatic conditions. This Chair not only strengthens our research capacity but also positions UNIVEN as a key contributor to national and global efforts in sustainable water and environmental management. We are confident that the knowledge and expertise developed through this initiative will have a lasting impact on our communities, the country, and the African continent."

BACK TO TOP

GLOBAL

Face masks could release harmful microplastics, chemicals

The global use of face masks surged during the COVID-19 pandemic, but many have since been discarded as waste, contributing to land and water pollution.

Dr Anna Bogush and Dr Ivan Kourtchev from Coventry University's Centre for Agroecology, Water and Resilience, placed unused masks in glass beakers, containing ultra-pure water and left them undisturbed at room temperature for 24 hours. The water was then filtered and analysed in the lab using advanced laboratory techniques to identify the types and quantities of microplastics and chemicals released, with strict controls in place to avoid contamination.

Even without wear or movement, the masks were found to release microplastic particles and chemical additives into the water, suggesting that these pollutants are already present from the manufacturing process. The study found that filtering facepieces released three to four times more microplastic particles than standard surgical masks. The micro particles released by the masks mostly comprised polypropylene, a common plastic used in mask production. Other plastics such as polypropylene, polyester, nylon and PVC were also detected, especially in the filtering facepieces. Since these materials don't easily break down, they can accumulate in the environment, causing harm to ecosystems and wildlife that may ingest or become entangled in them.

Some of the materials can also carry chemical additives that, once in the body, may disrupt hormones or negatively affect human health. In addition, the researchers discovered that chemicals, including Bisphenol B, were released from some types of masks into the water. These substances are known to harm fish and other organisms that live in water and could also affect people if they enter the food chain, pollute water sources or build up in the environment over time.

"This study has underlined the urgent need to rethink how we produce, use and dispose of face masks," noted Dr Bogush. "We can't ignore the environmental cost of single-use masks, especially when we know that the microplastics and chemicals they release can negatively affect both people and ecosystems.

"As we move forward, it's vital that we raise awareness of these risks, support the development of more sustainable alternatives and make informed choices to protect our health and the environment."

The invisible plastic threat you can finally see

Researchers at the universities of Stuttgart and Melbourne have developed an 'optical sieve' for detecting tiny nanoplastic particles. It functions like a test strip and is designed to serve as a new analytical tool in environmental and health research.

The research results have been published in ***Nature Photonics***.

Nanoplastic particles are created through the breakdown of larger plastic particles, and can't be seen by the naked eye. They have been found to cross organic barriers, such as the skin or blood-brain barrier.

Because of their small size, the detection of nanoplastics poses a particular challenge. As a result, there are not only gaps in our understanding of how particles affect organisms but also a lack of rapid and reliable detection methods. This new method is expected to help solve this challenge.

Colour changes on a special test strip make nanoplastics visible in an optical microscope and allow researchers to count the number of particles and determine

"The test strip can serve as a simple analysis tool in environmental and health research," noted Prof Harald Giessen, Head of the 4th Physics Institute of the University of Stuttgart. "In the near future, we will be working toward analysing nanoplastic concentrations directly on site. But our new method could also be used to test blood and tissue for nanoplastic particles."

• To view the original article, visit: https://www.nature.com/articles/s41566-025-01733-x

BACK TO TOP

Gender gap in Africa's water leadership undermines fair policymaking – analysis

Women experience major consequences from water scarcity and pollution. Yet they remain underrepresented in leadership and decision-making in water governance, leaving policies disconnected from the realities they face.

A new publication by the United Nations University Institute for Water, Environment and Health (UNU-INWEH) has found that women remain significantly underrepresented in water governance across Africa. The analysis reveals that only 17% of national ministries responsible for water in Africa are led by women.

Moreover, just one out of eleven transboundary water organisations is headed by a woman, highlighting the absence of women's voices in regional cooperation and decision-making on shared water resources. At the academic level, only 13% of universities offering water science programmes are led by women, further highlighting their underrepresentation in the field.

"These figures confirm that women in Africa are often left out of key leadership positions in the water sector, which may lead to policies that fail to address their health and sanitation needs fully," said Prof Grace Oluwasanya, lead author of the publication and senior researcher at UNU-INWEH. "This means that commitments to gender equality in water have not been fully realised, and urgent efforts are needed to ensure women have a decisive role in decision-making."

The authors note that the gender gap in Africa's water sector is driven by social and institutional barriers. These include traditional gender bias and limited access to technical education, which restrict women's opportunities to reach leadership roles. The analysis also identifies limited networking, weak mentorship, and restrictive recruitment and promotion practices as obstacles to women's advancement.

"Excluding women from leadership weakens governance and undermines progress on water security and the Sustainable Development Goals," said Prof Kaveh Madani, Director of UNU-INWEH. "Africa cannot afford to leave out key stakeholders in water governance. Women must be equally represented in shaping policies and decisions that directly impact them."

Several African countries have already begun to challenge the gender imbalance in water leadership. For instance, Kenya's Water Services Regulatory Board introduced guidelines requiring at least 33% female representation on utility boards, and Uganda's National Water and Sewerage Corporation introduced leadership programmes for women in the sector.

• To view the report, ***Women in Africa's water leadership – The numbers don't lie,*** visit: https://unu.edu/inweh/collection/women-africas-water-leadership-numbers-dont-lie

BACK TO TOP

GROWING MORE WITH LESS: SA ORCHARD IRRIGATION TOOL TAKES TOP GLOBAL HONOUR

A pioneering Decision Support System (DSS) for monitoring orchard water use, developed in South Africa, has won the international Watsave Innovative Water Management Award from the International Commission on Irrigation and Drainage (ICID).

The award was presented during a special ceremony on 6 September 2025 at the Fourth World Irrigation Forum in Malaysia. The DSS was developed by Dr Sebinasi Dzikiti from the Department of Horticultural Science at Stellenbosch University and his team, with funding support from the Water Research Commission (WRC) and the Inkomati-Usuthu Catchment Management Agency (IUCMA). This is South Africa's sixth WatSave award since its introduction by ICID in 1997.

The DSS estimates crop water requirements, yield, and irrigation requirements for several subtropical fruit tree crops, including mango, litchi, macadamia, citrus and grapefruit, which are key irrigated fruit in the Inkomati-Usuthu water management area (IUWMA). This innovation is expected to transform irrigation management in South Africa's subtropical fruit industry, enhancing water use efficiency, reducing waste, and helping growers adapt to increasing water scarcity.

Frequent droughts, climate variability, and growing competition for water have placed enormous pressure on fruit producers to improve water productivity – producing more fruit with less water. The DSS directly addresses this challenge. Using 50 years of daily climate data in each of the more than 250 quaternary catchments in the IUWMA together with scientifically validated crop coefficients, the DSS predicts 1) orchard total evapotranspiration (water lost from trees and soil), 2) potential yield, 3) water use efficiency, and 4) orchard irrigation requirements. The DSS enables farmers and catchment managers to plan water allocation and irrigation more accurately, improving yields while conserving water.

"This tool takes the guesswork out of irrigation planning," explained Prof Sylvester Mpandeli, WRC Senior Research Manager: Water Use. "For the first time, fruit growers can access reliable, site-specific water use information right from their phones or computers from anywhere within the IUWMA – a huge step forward in sustainable irrigation management."

"This international award has illustrated that the WRC, together with partner organisation, the IUCMA, made the right decision by investing in this research," noted Prof Mpandeli. "We are excited about the fact that the Orchard Water Use DSS is now endorsed by the global community, and the idea can easily be transferred and implemented in other water-stressed fruit production regions. This is good news for the fruit industry and the farming community at large. This study also illustrates the positive outcomes that can be achieved from purposeful partnerships between the WRC and its industry stakeholders."

The development of the DSS builds on over two decades of WRC-funded research into orchard water use. Detailed field measurements from numerous citrus, grapefruit, litchi, macadamia and mango orchards – spanning different cultivars, canopy covers, and microclimates within IUWMA – were combined with the internationally recognised FAO 56 irrigation guidelines to create a robust tool for water allocation planning and irrigation scheduling.

Unlike other tools, the WRC DSS automatically calculates appropriate crop coefficients for each orchard from readily available information. This eliminates a major source of error in water use estimation, as crop coefficients can vary significantly with crop type, orchard age, planting density, irrigation system, and ground cover.

Currently, the DSS works only for the IUWMA, but the idea can be easily transferred to other locations. With climate change expected to exacerbate water scarcity in prime fruit-growing regions such as the IUWMA and other fruit-growing regions, such tools will be vital for sustaining agricultural production and rural livelihoods.

"Given that this tool was developed to address the specific needs of users in the IUWMA, we are very excited that we have been able to move this study from basic science to practice," said Dr Dzikiti. "We are truly humbled that our work has been recognised, not only locally, but also beyond our borders. It is the aim of our future work to scale up the study to other key irrigated crop types in other parts of the country. As with any scientific tool/product, robust validation of the tool is important and we hope this will also form part of future work."

Dr Marco Arcieri, President of the International Commission on Irrigation and Drainage (ICID), handing the Watsave award to Dr Sebinasi Dzikiti of Stellenbosch University.

BACK TO TOP

NEW WRC REPORTS

Development of a remote sensing-based evapotranspiration model for monitoring crop water use and yield estimation in rainfed systems

Rainfed agriculture, which dominates in the Sub-Saharan African region, faces heightened risk due to its vulnerability to climate change and limited adaptive capacity. South Africa's agricultural sector is already affected by multiple stressors, including water scarcity, changing pest and disease profiles, rising input costs, and a diminishing interest among young people in farming. Enhancing agricultural productivity, through increased output per unit of land and water, is critical to ensuring food security and economic growth. Remote sensing technologies provide scalable, spatially explicit data that are essential for monitoring crop conditions, water use, and productivity. This project sought to address multi-component objectives within the agricultural and geospatial domains of South Africa: delineation of smallholder agricultural field boundaries across diverse topographies and agroecological zones; mapping of maize crop evapotranspiration (ET) using remote sensing and meteorological data for selected sites in Gauteng Province; and development of a geospatial tool for field-scale crop water use monitoring on a cloud computing platform.

WRC report no. 3226/1/25

Link: https://bit.ly/46ELmaa

Sustainable electrochemical reduction of contaminants of emerging concern and pathogens in WWTP effluent for irrigation of crops – SERPIC

The objective of the SERPIC project was to develop a new technology to remove contaminants of emerging concern like residues from pharmaceuticals and pesticides, and antimicrobial resistant bacteria from the effluent of wastewater treatment plants (WWTP). Those compounds and pathogens are dangerous for the environment and human health, but are mostly not removed by the existing treatment steps in municipal WWTPs. This creates risks for aquatic life as the treated water from WWTPs is usually discharged into surface waters. Furthermore, it hinders the reuse of the treated water, e.g., for the agricultural irrigation of crops, because the compounds might be accumulated in the soil and in the plants. The concept of the SERPIC technology is designed not only to remove the compounds from the water but to destroy them by oxidation so that they are removed from the environment and the water cycle. The first process step of the SERPIC technology is nanofiltration. The membrane separation allows for the production of a permeate of high quality. To create a multi-barrier approach, a subsequent in-situ disinfection via electrogenerated ozone gas was implemented, also allowing the removal of some CECs not rejected by the NF membrane. The project results showed that all six of the selected target compounds or pathogens are reduced via this two-step treatment by more than 90 % of the inlet contents. The concept of SERPIC is to reuse this stream for the irrigation of crops

WRC report no. 3225/1/25

Link: https://bit.ly/46DbBh7

Water use and nutritional water productivity of bush tea

Bush tea (*Athrixia phylicoides DC.*) is an indigenous shrub of South Africa known for its medicinal properties. However, due to a lack of comprehensive information on developing suitable irrigation management strategies, the cultivation of bush tea is currently limited to small-scale operations. Considering this limitation, the first aim of this project was to investigate the effect of water regimes on growth and development, yield, and nutrient content, along with its nutritional water productivity under field conditions. The result of the study highlights the significant influence of different water regimes on the growth and yield of bush tea plants. The highest yield was observed in plants subjected to 100% ETc, with a subsequent decrease in those under 30% ETc and water stress treatments. Notably, the 30% ETc treatment positively impacted soil water content, nutritional composition, and water productivity, highlighting the importance of optimising water application in bush tea cultivation.

WRC report no. 3223/1/25

Link: https://bit.ly/4pY3X8E

To download any of these reports
click on the web link provided, email:
hendrickm@wrc.org.za or visit: www.wrc.org.za

DIARY

Handwashing
15 October

Global Handwashing Day is a global advocacy day dedicated to increasing awareness and understanding about the importance of handwashing with soap as an effective and affordable way to prevent diseases and save lives. Visit: https://bit.ly/48lVXIm

Groundwater
28-31 October

This 19th Biennial Groundwater Conference will be hosted at the Magalies Park Resort, North West. It is expected that the conference will stimulate and encourage open conversation and deliberations – across disciplines – around the burning topics that impact groundwater. https://bit.ly/48qw5uV

Integrated water resource management
29-31 October

The 26th WaterNet/WARFSA/GWP-SA Symposium will be held virtually and in Lusaka Zambia, under the theme, 'Accelerating implementation of integrated water resources management in order to close the water investment gap by 2030 and beyond in Southern and Eastern Africa'. The Ministry of Water Development and Sanitation, Republic of Zambia is the lead host. Visit: https://bit.ly/4mNxNd3

GROUNDWATER-DEPENDENT ECOSYSTEMS

AI and satellites unlock secrets of Kruger's hidden water lifelines

Study leverages the power of remote sensing and machine learning to analyse groundwater-dependent ecosystems in the Kruger National Park (KNP). Article by Jorisna Bonthuys.

The Kruger National Park's ephemeral river drainage systems, or seasonal rivers, play a vital role in its biodiversity. These rivers only flow during the rainy season, drying up during the drier months. Although their existence is temporary, they have a significant impact on the landscape. During the rainy season, their waters carve out channels, deposit nutrient-rich sediments, and recharge underground water sources.

The interaction between ephemeral rivers, groundwater, and soil moisture is crucial for understanding the link between hydrology and groundwater-dependent ecosystems and for ensuring informed water management in the park. However, studying these ecosystems is challenging because of the park's vast size, its highly dynamic hydrological processes, and the limited availability of data. These factors make it difficult to fully grasp how water moves through the landscape and sustains the diverse life dependent on it.

Recently, Prof Timothy Dube and collaborators used machine learning and remote sensing to enhance their understanding of groundwater-dependent ecosystems in the park. Dube, the Director of the Institute for Water Studies at the University of the Western Cape (UWC), worked with Dr Tatenda Dalu from the University of Mpumalanga and Dr Mbulisi Sibanda from UWC on this project. Their research, funded by the Water Research Commission (WRC), demonstrated how advanced geospatial techniques can help decode the connections between groundwater resources and biodiversity in the KNP and other dryland regions.

BACK TO TOP

Robust framework to assess ecological health

Using advanced geospatial methods, the scientists mapped groundwater-dependent ecosystems in the southern region of the KNP. They combined spatial data, satellite imagery, and machine learning algorithms to delineate these areas accurately. Unlike other parts of the park, which receive ample surface water from rainfall, the southern region, especially around Pretoriuskop, is characterised by deep sandy soils, low rainfall, and limited surface water. Here, groundwater is crucial for supporting many plants and the animals that rely on them.

The researchers carried out an extensive review of existing literature alongside field surveys to collect real-world data on vegetation and soil moisture. This on-site data was essential for developing, calibrating, and validating the estimates generated from satellite observations. Additionally, the team studied how fluctuations in water availability impact local macroinvertebrate populations, which serve as important indicators of ecosystem health.

To understand future risks, they developed and tested predictive models to assess how groundwater-dependent ecosystems might respond to different climate change scenarios and environmental stresses. This comprehensive approach allowed for a deeper understanding of the complex interactions between water resources and biodiversity in the region. Together, these efforts allowed the team to create a comprehensive framework for monitoring groundwater-dependent ecosystems in the study area.

By integrating remote sensing technologies with field data, this framework provides a robust way to assess ecological health. It utilises satellite-based spatiotemporal models to enhance understanding and support informed decision-making for effective ecosystem management.

The team's project report, titled ***Remote sensing of groundwater-dependent ecosystems in the Kruger National Park, South Africa*** (**WRC report no. 3214/1/25**), emphasises the critical role that satellite-based monitoring can play in conservation efforts both within the park and in other dry or semi-arid regions. The document details how combining advanced remote sensing technologies with field data enables more accurate and timely assessment of groundwater-dependent ecosystems, which are often difficult to monitor using traditional methods due to their ephemeral nature and the vast scale of the landscapes involved.

By providing continuous, large-scale insights into changes in vegetation health, soil moisture, and hydrological dynamics, satellite monitoring offers a powerful tool for detecting early signs of ecological stress and guiding adaptive management strategies. The findings underscore the potential for this approach to improve water resource management, preserve biodiversity, and enhance resilience against the impacts of climate change in vulnerable environments.

The framework allows the researchers to accurately estimate and delineate water availability as well as groundwater-dependent ecosystems, particularly in non-perennial rivers that only flow intermittently. Achieving approximately 85% accuracy in these assessments is a significant breakthrough, especially in semi-arid and dry regions where traditional monitoring techniques, such as manual water sampling or short-term field observations, frequently fail to capture the full picture due to the variable and often unpredictable nature of water sources.

"This level of precision provides a reliable means of identifying critical water-dependent habitats, tracking changes over time, and informing more effective conservation and water management strategies," Prof Dube says. "As a result, the framework not only enhances scientific understanding of these fragile ecosystems but also helps land managers and policymakers make better decisions to safeguard water resources and biodiversity in challenging environments."

The project team worked closely with scientific teams from the KNP, which played a crucial role in fostering strong social capital both within and surrounding the park. The project's spatial data for the study area were, for instance, sourced from the KNP.

Using technology to gain a new understanding

Groundwater-dependent ecosystems are increasingly under pressure from human-wildlife and climate-related stresses, including changes in hydrology, rising temperatures, and shifts in land use. Unfortunately, effective management and conservation of these ecosystems are often hindered by a lack of comprehensive data regarding their condition, structure, function, and resilience. "At this stage, our understanding of the spatial distribution, vegetation composition, soil moisture dynamics, and water quality of these ecosystems, particularly in Africa, remains insufficient," says Prof Dube.

The researchers say recent advancements in geospatial artificial intelligence, which combine spatial analysis with artificial intelligence and medium-resolution satellite data, can, however, help bridge current knowledge gaps about groundwater-dependent ecosystems. Integrating remote sensing – using satellite or aerial imagery – provides almost the necessary scale and precision needed to map the connections between groundwater flow and dependent ecosystems in the park and beyond.

"Increasingly, technological advancements allow us to respond to environmental changes in real-time, optimise water usage, and develop predictive models for better resource planning

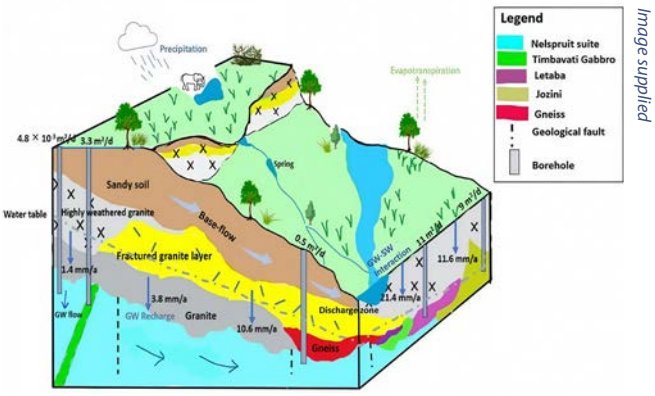


Image supplied

A hydrogeological conceptual model of the southern granite supersite in the Kruger National Park.

Lani van Vuuren

The windmills and borehole-dependent reservoirs dotted around the Kruger National Park are a reminder of the park's high dependence on groundwater.

in dryland regions," Prof Dube explains. These advancements are transforming the collection and analysis of biodiversity and freshwater data, he points out.

With remote sensing, researchers can detect whether groundwater-dependent ecosystems are expanding or shrinking over time. The effectiveness of remote sensing in mapping these ecosystems, however, depends on the spatial and spectral resolution of the imagery used, which is particularly important since small wetlands may cover less than one hectare.

The researchers highlight that advancements in data analytics, particularly through cloud computing platforms, present significant opportunities to improve data collection and analysis for monitoring groundwater-dependent ecosystems via remote sensing technologies. Notably, Google Earth Engine offers a wealth of readily available geospatial data archives, including Sentinel-2 satellite data, along with advanced computational resources that researchers can use in the local context.

When combined with hydrogeological approaches, advanced geospatial techniques enhance the ability of resource managers and policymakers to make actionable data-driven decisions regarding biodiversity conservation in these ecosystems.

"While many remote-sensing studies have mapped groundwater-dependent vegetation at regional scales, few have incorporated ground-truth validation, limiting confidence in their accuracy," Prof Dube explains. "Earlier approaches often treated groundwater and surface water as separate systems, thereby oversimplifying hydrological dynamics. In contrast, this study demonstrates their continuous exchange, providing a more integrated and realistic understanding of groundwater–surface water interactions and their role in sustaining groundwater-dependent ecosystems."

This study advances groundwater-dependent ecosystem science by providing the first integrated framework for identifying and monitoring groundwater connections in ephemeral systems. "To the best of our knowledge, no study has mapped groundwater-dependent ecosystems in South Africa using geospatial techniques," Prof Dube points out.

Collecting data with field surveys

The researchers conducted a field survey in September 2022, during the late dry season when most of the pans in the southern KNP were dry. Some inundated pans were found in the Makuleke section of the park.

The analysis made use of the medium-resolution Sentinel-2 satellite dataset, focusing on imagery collected in 2018, 2019, and 2022. These selected years were particularly relevant because the rainfall in the park was consistently below the long-term average annual precipitation.

By examining data from these comparatively drier years, the team was able to better understand how reduced rainfall impacts water availability and groundwater-dependent ecosystems. This approach provided valuable insights into the resilience and vulnerability of the region's ecosystems under conditions of drought and water stress, which are expected to become more frequent with ongoing climate change.

A total of 23 study plots were used to sample vegetation data in the Makuleke and Letaba regions. Twelve natural pans from the Makuleke wetland system, located in the Pafuri area, were sampled, while the second set of plots was sampled in the Letaba region. The researchers employed machine learning predictions to identify groundwater-dependent vegetation potential zones along the Makuleke and Letaba regions. It demonstrated a connection between species diversity and changes in water levels.

The results confirmed that remotely sensed soil moisture data is effective for assessing soil moisture patterns within the KNP.

It also showed that macroinvertebrate communities in the study area were influenced by seasonal patterns of water level fluctuations, known as hydroperiods. These hydroperiods refer to the duration and timing of flooding or water presence, as well as the geological types in the pans. Notably, the results indicated that the duration and frequency of inundation in the study area have a significant impact on macroinvertebrate diversity. Specifically, low hydroperiods tend to result in a decline in biodiversity within pan wetlands.

BACK TO TOP

Furthermore, sediment chemistry, influenced by geological types, affected the nutrient content and substrate features essential for macroinvertebrate habitats. The quality of water was another crucial factor for groundwater-dependent ecosystems, with parameters such as pH and nutrient concentrations directly affecting the diversity, abundance, and health of macroinvertebrates in the study area.

New knowledge generated

The project demonstrated that freely available satellite data, such as Landsat and Sentinel, combined with advanced machine learning techniques, can effectively map groundwater-dependent ecosystems across large protected areas. Prof Dube says that the methodologies and insights developed in this study offer a scalable approach that can be adapted to other vulnerable ecosystems, thereby supporting conservation efforts and facilitating data-driven decision-making.

The findings highlight the importance of machine learning techniques and multi-source remote sensing data in identifying potential groundwater zones. "This project represents a significant step towards developing smart technologies that provide essential and timely information for resource managers, enabling them to make informed field decisions," Prof Dube states. "Additionally, it helps scientists make recommendations for the sustainable management of conservation areas."

These findings are critical as they establish robust methodologies for geolocating these systems, ultimately enhancing the protection of groundwater-dependent ecosystems in semi-arid regions.

By evaluating the interactions among geological, hydrological, and biological factors, the researchers provided a model for sustainable ecosystem management in climate-sensitive regions. As such, this research offers a replicable framework for understanding groundwater-dependent ecosystems in other semi-arid environments. "The methodology combining moderate-resolution satellite data, targeted field measurements, and machine learning integration makes this approach accessible across resource-limited regions," Prof Dube points out. "Recent advancements in cloud computing and open-access satellite platforms mean these techniques can be applied in other dryland areas."

Next steps

According to Prof Dube, there remains much to learn about aquifer recharge dynamics in the study area in relation to climate variations and the long-term impacts of human activities on aquifer sustainability. The team recommends using high-resolution data to capture extremely dry periods, enabling better identification of green areas that may represent potential zones for groundwater-dependent vegetation.

Image supplied

Among others, the research team studied how fluctuations in water availability impact local macroinvertebrate populations, which serve as important indicators of ecosystem health.

What are groundwater-dependent ecosystems?

Groundwater-dependent ecosystems consist of communities of plants, animals, and microorganisms that rely on available groundwater to sustain their structure and function. These are ecosystems that have access to subsurface water on which they depend for their survival. The alluvial floodplains, especially around the Limpopo, Levuvhu and, to a lesser extent, Shingwedzi rivers, are good examples of such systems in the Kruger National Park.

Groundwater-dependent ecosystems, such as wetlands and riparian zones, depend heavily on underground water, especially during dry periods. If the groundwater level drops, these unique ecosystems become stressed and may be threatened. Consequently, these ecosystems face substantial threats from changes in water cycles, rising temperatures, and alterations in land use.

The researchers also emphasise the need to expand future studies by integrating machine learning techniques, diverse spatial datasets, and groundwater hydrogeological modelling. They believe this combined approach will significantly improve the accuracy and detail of mapping groundwater-dependent ecosystems.

In addition, they highlight the importance of evaluating high-resolution satellite data for accurately delineating soil moisture within these ecosystems. "Such advancements will deepen our understanding of the abundance, diversity, and distribution of plant and animal species that rely on groundwater, ultimately supporting more effective conservation and management efforts," Prof Dube says.

Future research should incorporate the use of stable and radioactive isotope tracers in combination with advanced geospatial modelling techniques to better identify and understand the unique geological interactions related to groundwater throughout the year. "These isotope tracers would provide valuable information about the origin, movement, and age of groundwater, allowing scientists to trace water sources and flow paths with greater precision," Prof Dube says.

When integrated with a geographic information system (GIS), this approach can reveal spatial patterns and seasonal variations in groundwater dynamics that are otherwise difficult to detect. "Such detailed analysis will help confirm the presence and extent of groundwater-dependent ecosystems by providing direct evidence of how groundwater supports the flora and fauna in these areas," he adds. "Ultimately, this enhanced understanding will strengthen efforts to monitor, protect, and sustainably manage groundwater resources and the ecosystems that rely on them."

Future studies could also investigate the use of waterborne invertebrates to determine if certain pools are dependent on groundwater and to monitor their conditions over time. Additionally, researchers could examine how different growth stages of plants in the study area relate to climate change. This could involve analysing geological type, water availability, sediment chemistry, and water quality to develop targeted conservation and management plans for groundwater-dependent ecosystems.

Lastly, a comprehensive assessment of water quality is necessary, including how variations in chlorophyll levels correlate with species diversity in these ecosystems. (Chlorophyll levels indicate the amount of algae and cyanobacteria in a water body, with levels correlating to water quality.)

The research underlines the need for using conservation methods and other arid regions that are specifically adapted to individual situations instead of using a generic approach (a one-size-fits-all strategy). "Understanding the complex interactions between geological type, hydroperiod, sediment chemistry, and water chemistry necessitates the implementation of site-specific and hydroperiod-specific conservation and management strategies," Dube says. "This, for instance, provides wetland managers with proactive solutions to protect groundwater-dependent systems, ensuring the sustainable existence of diverse macroinvertebrate populations and the overall health of pan wetlands."

The researchers note that the methodology developed in this study holds promise for future studies wanting to gain insights applicable to various global ecosystems, particularly those reliant on groundwater. "This study offers a step toward developing smart technologies that provide essential and timely information for resource managers to make in-field decisions and for scientists to offer recommendations for the sustainable management of conservation areas in South Africa. Ultimately, it contributes to a broader understanding of groundwater-dependent dynamics and enhances strategies for preserving these vital ecosystems in the face of global environmental change," they conclude.

To download the report, ***Remote sensing of groundwater-dependent ecosystems in the Kruger National Park, South Africa*** (**WRC report no. 3214/1/25**), visit: https://www.wrc.org.za/wp-content/uploads/mdocs/3214%20final.pdf

BACK TO TOP

INDIGENOUS CROPS

Study sheds light on the mysteries of medicinal Pelargonium sidoides

Once treasured as a traditional medicine, Pelargonium sidoides is now a globally recognised remedy. But what do we know about the cultivation of this wonder plant? Newly concluded research has provided much needed answers. Article by Petro Kotzé.

Jacki-Dee/Flickr

Even those unfamiliar with ***Pelargonium sidoides*** could likely have benefited from the plant's medicinal properties. A member of the Geraniaceae family, it flourishes in its endemic habitats in the Eastern Cape and Free State provinces, as well as in Lesotho. Commercial extracts of ***P. sidoides's*** bitter roots are sold worldwide in syrups, tablets, and lozenges. Popular brands include Linctagon C and Umckaloabo.

Yet, the tufted pelargonium, with its velvety silver leaves and near-black flowers, is still not being grown on scale to the benefit of communities that first uncovered the plant's medicinal properties.

Cultivating the plant, which is often harvested from the wild, is not straightforward. Ulrich Feiter, CEO of Parceval Pharmaceuticals, which grows the plant locally for export, points out that it took years of experimentation before they were able to do so successfully on a large scale. Due to the interest and commitment of companies such as Schwabe and Parceval over the last decades, the occurrence, genetics, propagation and cultivation of ***Pelargonium sidoides*** is probably the best studied and understood of any medicinal plant in South Africa.

However, much of this knowledge is protected by companies that benefit from it commercially, and little is publicly known

BACK TO TOP

about how irrigation, harvest timing, and water stress affect the plant's yields or medicinal qualities – knowledge that could provide an opportunity for small-scale farmers to tap into a lucrative value chain.

There could be more benefits to the successful cultivation of ***P. sidoides.*** It would ensure an authentic supply of the plant (that is easily confused with other species**,** especially ***P. reniforme***). It would help conserve the species in the wild. It could be more readily used as a health supplement in rural communities and create a sustainable and legitimate supply for buyers.

Working towards these goals, a Water Research Commission (WRC) funded project (concluded earlier this year) investigated the best methods for cultivating the pelargonium. The project assessed the growth of ***Pelargonium sidoides*** under three different irrigation conditions and the effect of these conditions, as well as harvesting age, on the plant's root yield and chemical composition. The research team also studied how water stress affects the activity of soil microbial enzymes and soil quality.

However, as WRC's Assistant Research Manager, Dr Samkelisiwe Hlophe-Ginindza explains, the project is about more than just science. It is also about making the findings practical, accessible, and beneficial for farmers and communities. "We need to ensure the work leads to real-world impact," she says.

The project was conducted by researchers from the Cape Peninsula University of Technology (CPUT), the universities of the Western Cape and Johannesburg and the Agricultural Research Council (ARC). They grew the pelargonium in pots under tunnel conditions at the ARC facilities at Infruitec-Nietvoorbij in Stellenbosch, completing two harvests and continuing observations beyond the official reporting period, for a third harvest.

The paradox of stress: when less water means more medicine

The researchers found that the plant adopted various strategies in response to water stress. Overall, the well-watered plants exhibited superior performance across morphological, physiological, and yield parameters. However, the fresh and dried root yield of the moderately stressed plants was better than that of the well-watered plants during the second harvest.

Then, as water deficit became more intense, most of the measured plant parameters experienced a decline again. Too much soil moisture also led to root rot in some of the well-watered plants. Still, the plant is drought-tolerant, says project leader Dr Nike Lewu, a senior researcher at ARC Infruitec-Nietvoorbij, and it can be successfully cultivated commercially without the need for complex irrigation systems.

An intriguing finding resulted from chemical analysis of the plants. The phytochemical analysis of ***P. sidoides*** extracts revealed the presence of saponins, flavonoids, terpenoids, phenols, tannins, and coumarins across all irrigation levels and harvest ages. However, under water stress, the plants produced more secondary metabolites. "The secondary metabolites, the compounds responsible for the plant's healing effects, increase when the plant is under stress," Dr Lewu explains.
Flavonoid levels were highest at moderate irrigation, while coumarins peaked under severe stress.

Dr Lewu notes that under drought conditions, the plant produces more coumarin – the compound that makes it so effective against respiratory infections. "After six months of stress, we saw an increase in secondary metabolites. After 12 months, even higher. At 18 months, they declined, but remained higher than the first harvest. We suspect that the season also plays a role, winter plants were richer than those in summer."

In short, stress doesn't just harden the plant's will to survive; it strengthens its medicinal power.

The findings highlight the importance of proper irrigation guidelines for the cultivation of ***P. sidoides*** and for continued funding to do so. This is especially important since the plants only mature at four to five years. "Without a full four- to five-year cycle, we cannot yet provide farmers with complete cultivation guidelines," Dr Lewu says.

Taking the findings to the farmers

The findings were presented at a workshop in Stellenbosch this September. It brought together funders, farmers and policy-makers. Dr Hlophe-Ginindza notes that the workshop created an opportunity for people to talk and ask questions, and for bonds to be formed between farmers, markets and stakeholders.

The event formed part of the execution of a broader WRC

A true wonder plant

Pelargonium sidoides is known variously as the African geranium, Umckaloabo, Uvendle (isiXhosa), Kalwerbossie (Afrikaans), iYeza lezikali (isiXhosa), Icwayiba (isiXhosa), ikhubalo (isiXhosa), Rabassam (Dutch/Afrikaans) and Khoaara e nyenyane (Sesotho). "It's the true Mzansi for sure," says species expert, Prof Francis Lewu, a researcher at the Cape Peninsula University of Technology (CPUT).

The roots contain powerful antibacterial and antifungal properties. Their coumarins and flavonoids support immune responses and fight infections, especially respiratory illnesses. Its traditional uses span an impressive list, including tuberculosis, bronchitis, coughs, fevers, diarrhoea, gonorrhoea, liver disorders, infant stomach ailments, and even colic in livestock. Pelargonium is not new to the global market. Germany and other countries have long commercialised extracts such as Umckaloabo for respiratory illnesses. Yet, despite being the plant's natural home, South Africa has not built a strong local value chain to harvest the benefits the plant offers.

BACK TO TOP

Capacity building during the project
The September workshop, *Effect of irrigation and harvesting age on the growth, yield and chemical composition of Pelargonium sidoides DC*, provided three WRC-funded students the opportunity to present the results of their research. Phila-Sande Ntoyi (registered at the Department of Biotechnology, UWC) presented on the morpho-physiological and biochemical responses of *P. sidoides* leaves to water stress; Yandiswa Mtimkulu (studying towards a PhD degree in Agriculture at CPUT) presented on the morphophysiological responses, yield and nutritional composition of *P. sidoides* to water stress at different harvest age; and Kundani Khameli (registered at the University of Johannesburg (UJ) for a PhD degree in Biotechnology) presented on the root chemical composition of *Pelargonium sidoides* in response to irrigation and harvesting age.

strategy shift. The commission's Strategic Plan for 2025/26 to 2029/30 emphasises real-world impact, stakeholder engagement, and knowledge uptake. Rather than producing reports that gather dust, Dr Hlophe-Ginindza says, the WRC is pursuing practical research that answers the question: "Then what?"

Key elements of this approach include stakeholder engagement, the use of demonstration sites to move research out of laboratories and into farmer fields, and co-producing knowledge by working alongside communities. Dr Hlophe-Ginindza adds that the new strategy calls for a focus on the entire value chain, and looking beyond production to marketing, processing, and opportunities for youth. Furthermore, the WRC is employing more accessible communication methods to disseminate research findings, including the use of YouTube videos, workshops, and plain-language summaries.

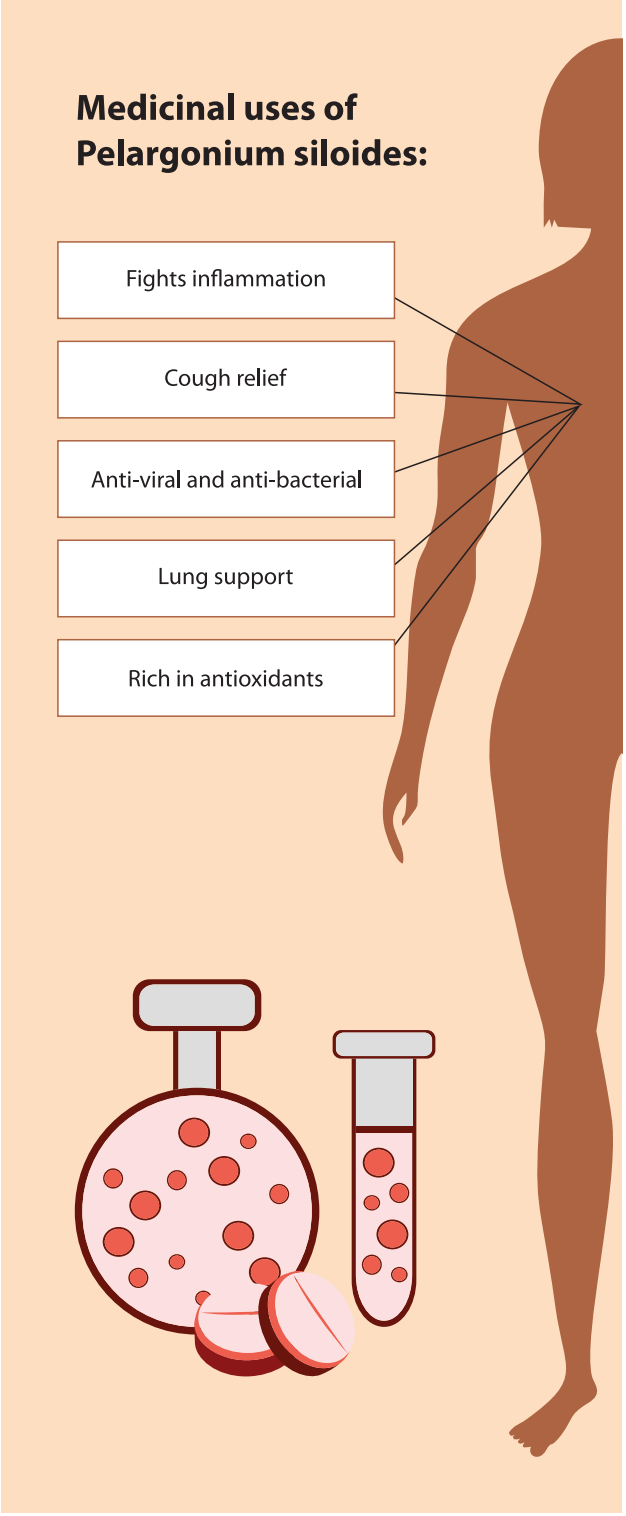
"Good science must always lead to action," she says. "It must change behaviour, create livelihoods, and improve resilience. Otherwise, we are only filling shelves with paper."

Looking ahead: from roots to livelihoods
The next steps for pelargonium research will be critical. The team hopes to continue monitoring plants to full maturity (four to five years) and develop practical irrigation and harvest guidelines. Dr Hlophe-Ginindza notes that establishing demonstration plots in farmer sites will ensure co-creation of knowledge and enhance its uptake. Additionally, training the youth and farmers would be an important step forward in ensuring communities benefit from the plant's cultivation and value chain development.

Prof Lewu adds that future research directions to consider include refining propagation techniques, explaining the plant's phytochemical properties, establishing policies to regulate harvesting and the formation of Public Private Partnerships, which he pointed out as "an important part moving forward."

A proposal for extended funding from the WRC has been submitted and is under consideration. Until then, Dr Lewu says they will continue to monitor the plants at the ARC.

To access the report, ***Effect of irrigation and harvesting age on the growth, yield and chemical composition of Pelargonium sidoides DC,*** (**WRC Report No. 3201/1/25**), visit: https://wrcwebsite.azurewebsites.net/wp-content/uploads/mdocs/3201%20final.pdf



WATER-RELATED DISEASES

Closer scrutiny needed to manage outbreaks of Legionnaires' disease in SA water systems

Researchers have found significant levels of Legionella bacteria in both inner city and rural water distribution systems in South Africa, emphasising the need for better monitoring, management and maintenance of these systems. Tony Carnie reports.

Legionnaires' disease is a severe form of pneumonia caused by the contamination of water with ***Legionella*** bacteria. These bacteria are ubiquitous in nature and can also spread and settle in treated drinking water systems – especially in large buildings or when distribution systems are old or poorly maintained.

The disease was only discovered following the first known outbreak in 1976. It started in a high-rise hotel in the United States during a convention of American Legion military veterans – hence the name Legionnaires' disease. Despite prior chemical treatment and the high water temperatures in geysers, these opportunistic pathogens can survive stressful conditions in water distribution systems and cause ***Legionellosis*** (also known as Pontiac fever or Legionnaires' disease).

Symptoms include a severe headache, fever, chills, chest pains and dry cough, and can be fatal – especially in vulnerable populations. Older people and those with compromised immune systems, including people with HIV and tuberculosis, are at increased risk of infection, with only 5% of healthy individuals likely to develop the disease. In Europe, the number of cases of ***Legionellosis*** reported in 2017 shows an incidence rate of between 1.8 and 2.2 per 100 000 people.

Previous studies in South Africa suggest that reported cases of Legionnaires' disease in South Africa are relatively low compared to other waterborne diseases, such as cholera and typhoid fever. For example, 12 cases were found at a Johannesburg teaching hospital during 1985 and another 93 cases were reported between 2018 and 2020, mostly in older men in hospitals in the Western Cape. More recent data have shown that the Western Cape reported the most cases of ***Legionellosis*** (20 cases) from March to August 2023. This was followed by Gauteng province with five cases in 2023.

Globally, the threat from Legionnaires' disease is compounded

BACK TO TOP

because its victims tend to show the same symptoms as patients infected with the Covid-19 coronavirus, including cough, chills, and fever - making misdiagnosis a possibility.

A new research project funded by the Water Research Commission (WRC) cautions that the incidence of Legionnaires' disease in South Africa may be underreported due to diagnostic limitations or misdiagnosis, with many cases possibly obscured by similar symptoms to other respiratory illnesses, such as pneumonia. Due to increasing urbanisation, aging infrastructure, and climate change, the public health threat posed by ***Legionella*** is also expected to rise, the report warns.

It further notes that South Africa is faced with the dual epidemics of HIV and TB, as well as resource and medical care limitations. "This heavy burden of disease creates both a diagnosis bias, hiding many other diseases, and an immunocompromised population susceptible to many other diseases. This might explain the lower rate of reported ***Legionellosis*** cases in South Africa in comparison to developed countries."

The research team, hailing from four universities (Johannesburg, Venda, United Arab Emirates and Zimbabwe), collected and analysed water samples from a variety of urban and rural areas, including Hillbrow in Johannesburg, Atteridgeville township in Pretoria, rural settlements around Thohoyandou in Vhembe province and from the Zandspruit and Melusi informal settlements in Gauteng.

Notably, the híghest levels of ***Legionella pneumophila*** contamination were found in Hillbrow. Though the majority of tenants interviewed in the study had access to building geysers, many did not use them, opting for cold baths or boiling their own water. The researchers found that ***Legionella*** was highly prevalent in Hillbrow, particularly in cold tap water and geysers. Cold tap water showed moderate contamination, with several samples in the 11–100 MPN/100 mℓ range, while one building

Image supplied

Project leader, Dr Atheesha Singh, says Legionella *bacteria pose a public health risk in both urban and rural areas, particularly where water systems are poorly maintained or where conditions favour bacterial growth.*

Image supplied

The position of water storage tanks on the roof can impact water quality as there is no shade and the warmer temperature promotes microbial growth.

sample exceeded 1000 MPN (Most Probable Number), indicating severe contamination.

Geyser water in Hillbrow showed lower contamination, with 13 samples in the 11–100 MPN range. Biofilm samples from taps and showerheads also showed contamination, pointing to potential challenges in maintaining safe water distribution systems in dense urban environments.

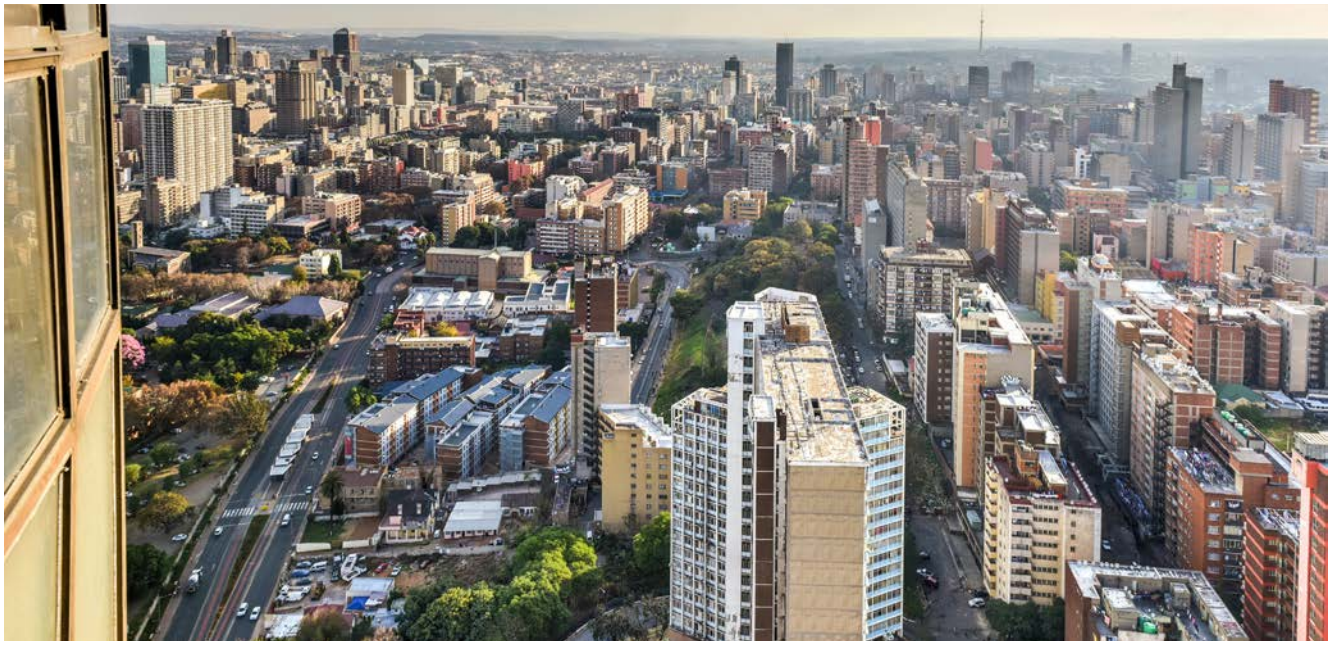
The researchers note that Hillbrow is one of the most densely populated metropolitan areas in Southern Africa, with limited records of plumbing renovations and maintenance. It has been estimated that there are nearly 75 000 people living here within just one square kilometre. With so many people cramped together (some in living rooms, small bedrooms or kitchens), this can impact personal hygiene, while the density of ageing piping in multiple-floor buildings can promote microbial growth.

In Vhembe, a rural area in Limpopo province, the study found considerable ***Legionella*** contamination, mainly in stored water and geysers, with several samples exceeding acceptable safety limits. In Vhembe, cold tap water contamination was minimal, with most samples below 1 MPN, but two samples fell into the 11–100 MPN range, and one sample exceeded 2272.6 MPN. Contamination was especially prominent in informal housing structures where storage tanks were not regularly maintained, allowing ***Legionella*** to thrive.

In Atteridgeville, contamination levels were moderate, at levels generally below those in Hillbrow and Vhembe. However, one cold water sample in Atteridgeville was above 2272.6 MPN/100mℓ. Geyser water was mostly uncontaminated and stored water followed similar trends, with most samples showing low microbial counts. However, biofilm samples from infrequently used taps and showerheads still showed contamination risks.

The informal settlements of Zandspruit and Melusi had relatively

BACK TO TOP



In densely populated urban areas, maintaining a consistent water temperature and ensuring adequate chlorination throughout the entire water system can be challenging. This is partly because of potential temperature differences while pumping water in older high-rise buildings.

lower levels of contamination. Although most of the samples from these areas fell within acceptable limits, a few exceeded the threshold, particularly in older storage systems and shared community taps.

In Zandspruit, microbial contamination was more pronounced, with 18 cold tap water samples in the 11–100 MPN range and one sample in the 101–1000 MPN range. In Melusi, microbial contamination was lower but still present, with seven cold tap water samples in the 11–100 MPN range. These results indicate that even in areas with lower population density, inadequate infrastructure and sporadic maintenance poses significant risks for ***Legionella*** growth.

Risk assessments suggest that contamination in these areas is driven by a combination of factors, including older infrastructure, biofilm formation, inadequate maintenance, and environmental conditions that promote ***Legionella*** growth. "This underscores the need for regular monitoring, system upgrades, and community-level education to mitigate the public health risks associated with ***Legionella***-contaminated water," the study notes.

Project leader, Dr Atheesha Singh, explained that ***Legionella*** often proliferate due to the gradual build-up of biofilms (hard or slimy layers of bacteria and fungi that form on the inner surfaces of water tanks and pipes, particularly in areas with mineral deposits or rough surfaces). Once established, biofilms become difficult to eliminate.

Singh, a microbiologist and senior lecturer at the University of Johannesburg's Water and Health Research Centre, said: "One of the most important lessons from our research is that managing water systems to reduce ***Legionella*** and biofilm growth requires a proactive, system-wide approach. It starts with the materials used in the plumbing systems. Certain plastics and ageing metals can support microbial growth or corrode over time, thereby creating rough surfaces that promote biofilm formation.

"In contrast, plumbing materials like copper pipes have been shown to inhibit bacteria . . . Thus, choosing the right materials at the design and construction phase of a water system can make a lasting difference in water safety."

Unfortunately, retrofitting water infrastructure in existing buildings is not always possible. However, she says that there are still practical methods to reduce the risks significantly – including regular maintenance. "Dead legs in plumbing systems (disused sections of pipe where water does not circulate) create ideal conditions for stagnation and microbial proliferation. Routine water system assessments are necessary to identify and eliminate these zones and to ensure consistent water flow throughout a building.

Temperature control also plays a key role. "Where feasible, hot water systems should be maintained at temperatures above 55°C, as ***Legionella*** is less likely to survive at higher temperatures."

This, however, must be carefully balanced with energy efficiency goals and the risk of scalding, particularly in residential areas.

Singh notes that chemical disinfectants, such as chlorine bleach, are widely used, but ***Legionella*** can still survive within protective biofilms, making them less susceptible to chemical treatment. A more effective strategy involves combining chemical disinfection with physical interventions, such as regularly flushing unused outlets, descaling tanks and pipework, and implementing a site-specific water safety plan.

At the household level, residents who rely on storage containers (such as buckets or JoJo tanks) should clean them regularly by using hot water and detergent to reduce microbial contamination. Taps and showers that are rarely used should be

BACK TO TOP

flushed out frequently.

Singh also recommends that monitoring and controlling ***Legionella*** should begin with routine environmental surveillance, especially in densely populated residential buildings with complex plumbing. "Water sampling should be conducted periodically, approximately every three to six months. Samples should be taken from hot water systems, storage tanks, and outlets that are seldom used, as these locations are prone to stagnation and biofilm formation."

These samples can be tested for ***Legionella*** using culture-based methods, which remain the gold standard for detecting viable bacteria.

"Where resources allow, molecular techniques such as polymerase chain reaction (PCR) offer quicker results and greater sensitivity. Screening tools like Legiolert® are being adopted for initial testing, as they are user-friendly, cost-effective, and capable of detecting ***Legionella pneumophila***, the species most commonly associated with disease, within seven days."

However, the choice of testing method and whether testing is done at all often depends on the availability of laboratory capacity and the feasibility of implementation. "In the South African context, microbiological testing is typically outsourced to accredited water laboratories, as most building facilities lack in-house capacity."

All actions should be guided by a Water Safety Plan with clear roles for building managers or caretakers. "Managing ***Legionella*** requires ongoing vigilance, not just during outbreaks, but as part of routine building maintenance and public health protection," she stresses.

While water utilities are responsible for delivering microbiologically safe water up to the point of distribution, residential property owners and occupants also have a critical role to play, especially where water is stored in tanks or drawn from alternative sources, by keeping containers clean, flushing unused outlets regularly, and ensuring household plumbing is maintained.

"Preventing ***Legionella*** requires practical, consistent action by all parties responsible for water management at different points in the system.

Image supplied

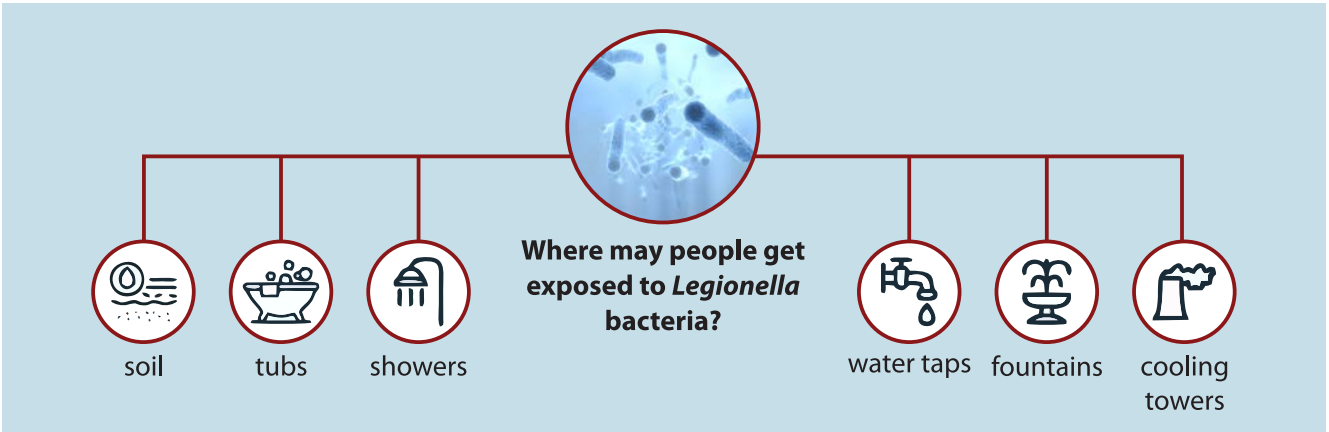
Water samples are collected from taps in Hillbrow.

"One of the overarching conclusions of this study is that Legionella prevention cannot be addressed through technical interventions alone. It must be understood within the broader context of socio-economic disparity, infrastructure fragility, and service delivery challenges that affect large parts of South Africa, particularly in densely populated, low-income urban areas."

These risks are further intensified by energy insecurity, especially load shedding, which disrupts the consistent heating of water systems and compromises the maintenance of safe temperature thresholds needed to suppress microbial growth.

"Similarly, intermittent water supply due to water cuts or scheduled rationing leads to stagnation within pipes and tanks, conditions that encourage the development of biofilms and the persistence of Legionella bacteria."

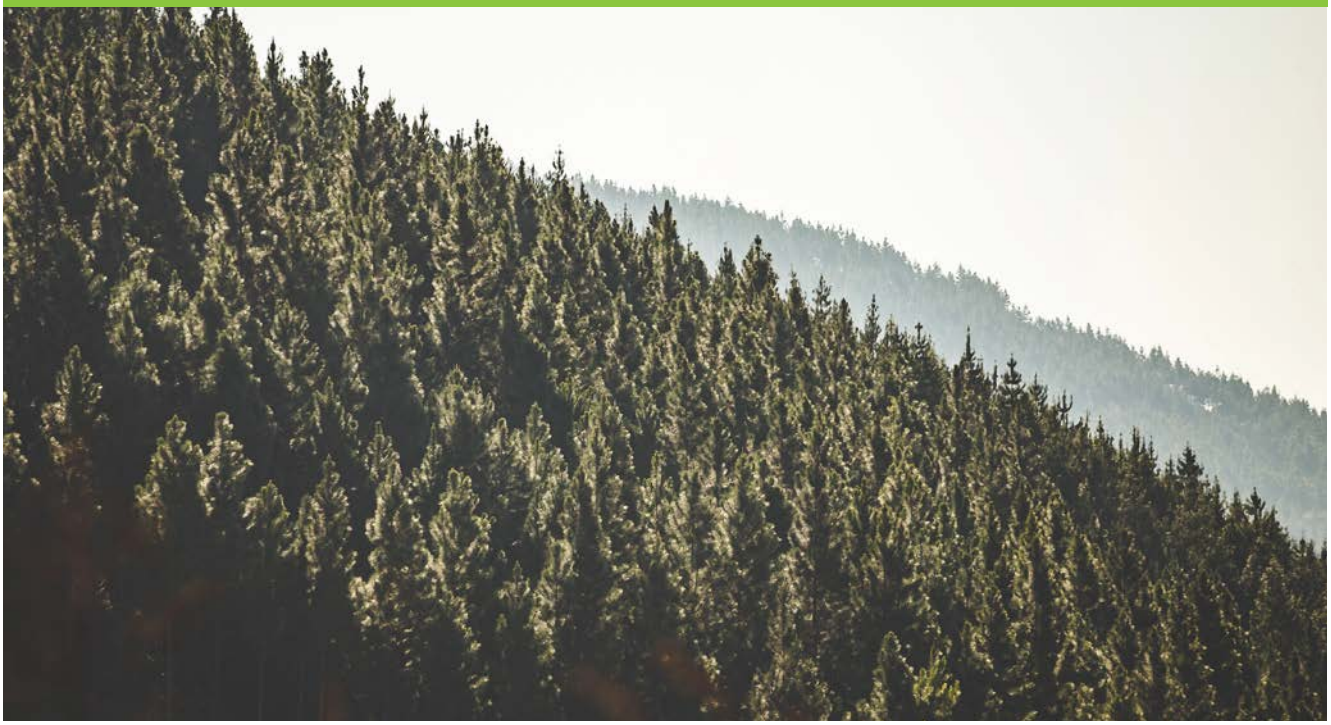
Singh says the study's findings will be disseminated widely. An information booklet on water safety and ***Legionella*** prevention will also be distributed to several stakeholders, including building managers and municipal authorities.



INVASIVE ALIEN PLANTS

Water vs wood: The high cost of alien trees in South Africa's catchments

A three-year research project, funded by the Water Research Commission (WRC), has made a significant contribution to addressing the issue of invasive alien plants in South Africa. The project provides imperative recommendations for managing this threat to the country's water security. Article by Alanna Rebelo and Lani van Vuuren, based on a policy brief, written by Alanna Rebelo, Liam Cogill, Thandeka Skosana, Karen Esler, Errol Douwes, Jackie Jay, Sipho Magagula, Bonani Madikizela, Christo Marais, Nicky McLeod, John Phangisa and Tendai Sawunyama.

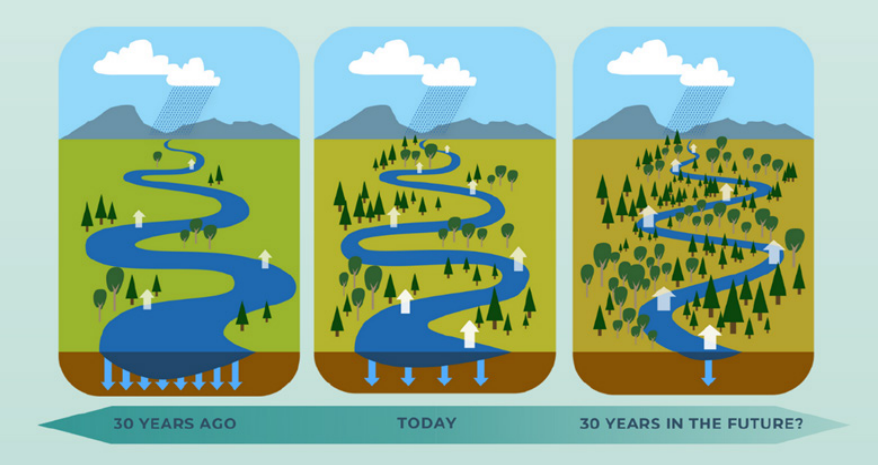


South Africa is one of the most water-stressed countries in the world. Rainfall is erratic, rivers often run dry, and climate change is intensifying the pressure. Yet, at the same time, millions of litres of precious water are being lost each year to invasive alien trees. These plants grow fast, spread rapidly, and use up far more water than native vegetation. They also fuel intense wildfires and crowd out biodiversity.

Running from 2022 to 2025, the Mapping Woody invasive Alien Plant Species (MapWAPS) project was a trailblazing initiative which piloted remote sensing approaches for mapping alien trees in different biomes, with the long-term vision of producing a national map. The project used freely available satellite imagery and machine learning to map invasive alien trees within catchments that intersect with strategic water source areas (areas which cover 8% of South Africa's surface but supply 50% of runoff). Water-related impacts were estimated using freely available remote sensing products and an ensemble evapotranspiration model built within the project, which was validated using 14 flux tower stations nationwide.

It is expected that these maps and tools will be critical for water resource managers, conservationists and policymakers to make informed decisions in protecting South Africa's water resources. By mapping the distribution, extent and impact of invasive alien trees, the team gained valuable insights which were taken into

BACK TO TOP



South Africa has long known that invasive alien trees threaten our water resources. The Working for Water Programme began in 1996 to stop the spread and reduce water loss. Yet, nearly 30 years later, the problem is growing, underscoring the need for upscaling investment and maintenance. We now face a choice: allow further invasion and impact, or act to restore our ecosystems.

consultations with experts from different government departments, non-profit organisations, catchment management agencies, parks managements and catchment partnerships. From these consultations, nine key statements with recommendations were distilled.

1. Clearing invasive alien trees in strategic water source area catchments has major water benefits

Clearing woody invasive alien plants in all four of the study catchments could release over 100 mm a year if they are restored to a native treeless ecosystem, such as grasslands, shrublands or wetlands. Even restoring to a treed ecosystem, such as a forest (where appropriate), produces water gains compared to alien tree invasions of wattle, pine, gum and poplar (by about 20 mm a year).

		NATIVE ECOSYSTEM		
		GRASSLAND	FOREST	WETLAND
ALIENS	WATTLE	76	17	68
	GUM	134	24	118
	PINE	113	16	114
	POPLAR	-	8	27
	BUGWEED	141	-	-
	LANTANA	111	-	-

Amount of water release in mm/year when restoring native ecosystems by clearing alien tree invasions (note: mm represents depth over an area, for example, 1 mm = 10 m^3/ha/year.)

If we cleared all the gum, pine and wattle invasions (not including plantations) in each of the four study catchments and restored these areas to native ecosystems, we would be able to free up approximately 110 million m^3 of water overall. This equates to water for over 770 000 households each year (based on 100 L per person, and four people per household).

2. Sustainable investment is key

This research has shown that alien trees have invaded between 1% and 5% of catchments within strategic water source areas. A publication by Kotzé et al (2025, https://rdcu.be/eEh2e) reported that the investment in alien tree clearing over the last 25 years in South Africa has not resulted in the desired reduction of invasion. Although the programme slowed the spread of alien trees, why was it not more successful?

Part of the reason, according to the experts engaged, is that investment has been insufficient (despite being substantial) as well as intermittent. This has made running alien tree-clearing programmes challenging. Permanence and security of jobs have been a major shortcoming and have had socio-economic consequences.

Sustainable investment into invasive alien tree clearing is critical. There needs to be a long-term, strategic vision with buy-in and

collaboration of all stakeholders. We recommend planning on a 50-year timeframe.

3. Clearing invasive alien trees within a restoration framework leads to water-related co-benefits
Clearing invasive alien trees followed by restoration to a native ecosystem not only makes more water available (water provision or yield) but also assists with water regulation. Infiltration is higher under native ecosystems such as grasslands or fynbos than under invasive alien trees or plantations.

This infiltration allows soil water stores to replenish and, in some cases, also allows aquifers to recharge. Slowing the movement of water through the landscape means that this additional water doesn't rush from the surface all at once, preventing flooding downstream as well as reducing drought risk. Therefore, invasive alien tree clearing within a restoration framework is a very important strategy for South Africa to consider in terms of climate change adaptation.

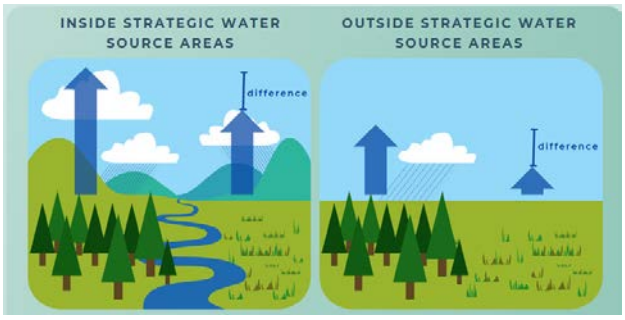
Clearing invasive alien trees with restoration helps to build resilience back into our ecosystems. Resilience means the ability of an ecosystem to recover after a shock, such as a flood, fire or drought. All these benefits imply that invasive alien tree clearing and restoration can contribute to securing the strategic water source areas in South Africa.

4. The relative water impact of invasive alien trees is consistent inside and outside strategic water source areas
The research has shown that inside strategic water source areas, invasive alien trees use more water, but so does the native vegetation. This means that, relatively speaking, the water impact of alien tree invasion, or clearing, is the same inside compared to outside strategic water source areas.

It is important to note that we didn't consider groundwater strategic water source areas, only surface water ones. It is possible that where invasive alien trees have access to a source of water that is not available to native vegetation (e.g. trees tapping groundwater that grasses with shorter roots cannot access), such as groundwater, invasive alien trees will use proportionally more water relative to native vegetation. More research on invasive alien tree impact on water resources in groundwater strategic water source areas should be an urgent priority, as it may advise priority areas for invasive alien tree clearing, where investment can have a larger impact on water availability.

5. Forestry in strategic water source areas trades economic gains for significant water costs
Having plantations within strategic water source area catchments presents a trade-off: these plantations have economic benefits, but they also have a major water cost relative to native ecosystems that they replace (even indigenous forests). In certain strategic water source areas, rezoning of land-use activities could be beneficial to protect water sources.

Considering actions such as the restriction of any further water use licences for plantation forestry in water-stressed catchments, as well as strategic water source areas, could be beneficial in terms of water resource management. Forestry companies wishing to reduce their water footprint could also consider genus swapping to taxa that consume less water within their specific bioclimate.



Invasive alien trees inside strategic water source areas use more water compared to those outside them; however, so does the native vegetation. Therefore, the relative amount of water freed up when clearing invasive alien trees and restoring to native ecosystems is the same, whether inside or outside of a strategic water source area.

6. Many alien invasions are a legacy of forestry
This study demonstrates that alien tree invasions are most severe in areas surrounding plantations and decline with increasing distance from them. Given that plantation forestry is a major driver of these invasions, the forestry sector should bear responsibility for managing and controlling their spread. This issue must be addressed by all entities within the sector, including both private companies and state-owned enterprises.

It is ethically indefensible for the citizens of South Africa to bear the financial burden of clearing invasive alien trees or suffer the resulting loss of ecosystem services, while forestry operations continue to profit without internalising the environmental costs they impose. Forestry companies must incorporate the costs of alien tree invasions into their pricing structures. If the true cost of forestry – including the ecological and economic impacts of invasions – were accurately accounted for, the sector's profitability might be significantly reduced.

Holding the forestry sector accountable for restoring the ecological degradation it has caused could incentivise more responsible practices. This includes increased private-sector investment in solutions such as the development of sterile cultivars and the advancement of biological control measures.

We recommend that the legislation around accountability for the spread of invasive alien trees be urgently strengthened. Companies and landowners should be legally required to clear alien trees that have spread from their plantations, regardless of how far they have dispersed, and to actively restore the affected ecosystems. In the longer term, we recommend that the government consider bans on the planting of tree species known to be major invaders. These are species that have cost the country billions of Rands in damages and hundreds of millions annually over the past 25 years in clearing efforts.

Such measures could be implemented through stronger wording and penalties in the National Environmental Management: Biodiversity Act (Act No. 10 of 2004), and subsequent revisions, as well as improved enforcement.

BACK TO TOP

The approaches we have developed could also assist the government with monitoring and compliance.

7. The water-related impacts of plantation forestry non-compliance

The study found widespread alien tree invasions within riparian zones (areas alongside rivers) across all four study catchments. These invasions are of particular concern, as invasive alien trees in riparian areas are known to have disproportionate impacts on water availability. Notably, we also observed that many plantations are located within these sensitive zones, in direct violation of environmental regulations. According to legislation guidelines, forestry operations are required to maintain a 20-metre buffer from the edges of rivers and wetlands.

Despite this obligation, our findings reveal frequent non-compliance, with numerous plantations extending directly into riparian zones and wetlands. If these areas were restored and companies brought into compliance, substantial volumes of water could be recovered. For example, in the Sabie-Crocodile catchments, 18.7 million cubic metres of water would be made available each year if plantations and alien tree invasions were removed from the riparian buffer zones.

We recommend that plantations should stay out of riparian zones and floodplains (e.g. above 10-20 year flood lines). To facilitate this, the government should strengthen inspection and enforcement mechanisms and enhance oversight of the Forest Stewardship Council certification process in South Africa.

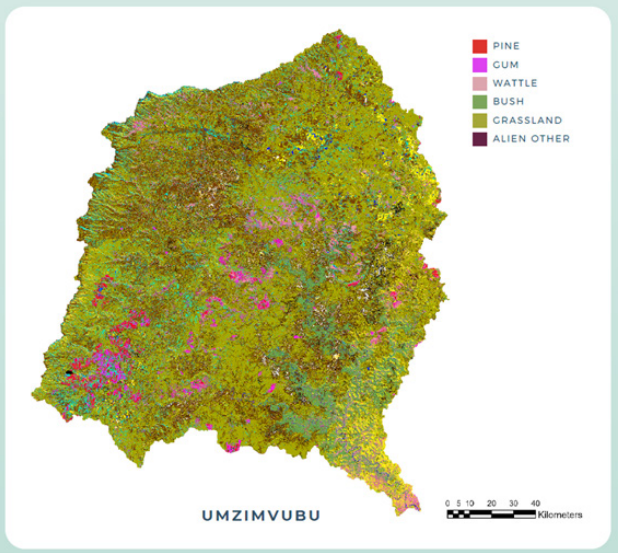
8. Up-to-date invasive alien tree maps are needed

Effective management of invasive alien trees requires accurate knowledge of their locations. Given the rapid rate at which these invasions spread, regularly updated maps are essential for timely and effective intervention. This highlights the need for a mapping approach that is both easily updatable and therefore readily repeatable. The MAPWAPS approach has been developed for this purpose and has achieved good accuracy results.

Investment in such a mapping process, and the resulting outputs, is critical not only for on-the-ground management, but also for fulfilling national and international reporting obligations, such as the National Biodiversity Assessment and commitments under the Global Biodiversity Framework. The method developed in this project offers a practical solution by providing a repeatable approach for generating regularly updated, national-scale maps of invasive alien trees. We strongly recommend that ecological expertise be a core requirement in the development and interpretation of these maps to ensure their accuracy and relevance.

9. A water-use calculator is needed to calculate the benefits of clearing invasive alien trees

We recommend investment into the development of a tool to enhance estimates of the water-use impacts of invasive alien tree clearing, using satellite remote sensing products as demonstrated in this study (Cogill et al. 2025, https://www.sciencedirect.com/science/article/pii/S235293852500165X). Such a tool could play a vital role in supporting evidence-based decision-making and ongoing monitoring in water resource management.



An invasive alien tree map of the uMzimvubu River catchment scored an overall invasive alien tree accuracy of 97%, and 94% for telling alien tree taxa apart.

Currently, the most widely used tool focuses solely on streamflow changes, based on the streamflow reduction curve concept. In contrast, the MaPWAPS approach captures comprehensive changes in water availability, including both surface and groundwater**.** This represents a significant advancement over existing methods and makes strategic use of freely available satellite imagery to improve water management.

Furthermore, this approach aligns with the government's priorities for digital transformation within the environmental and water sectors. A water-use calculator is needed to calculate the benefits of clearing invasive alien trees.

Conclusion

South Africa has been spending around R300 million a year on alien plant clearing programmes, yet invasions continue to spread. The MapWAPS project shows that better data can support smarter planning to make this investment go further. A more strategic approach to alien tree clearing could save billions of litres of water each year, protect biodiversity and build resilience against climate change. The United Nations has declared this the Decade of Ecological Restoration. We are already halfway through the decade, and the bulk of the work is yet to be done.

To access the final report, ***Mapping woody invasive alien plant species and their impacts in strategic water source areas*** (**WRC report no. 3193/1/24**), visit: https://www.wrc.org.za/wp-content/uploads/mdocs/3193%20final.pdf

To access the policy brief, ***Alien tree invasion in South Africa: Status and impacts on water in strategic water source areas***, visit: https://wrcwebsite.azurewebsites.net/wp-content/uploads/mdocs/Policy%20Brief_MAPWAPS.pdf

BACK TO TOP

ESTUARIES

From macro to micro: Tools for monitoring estuarine health and recovery

South Africa's estuaries are in crisis. A massive chemical spill near the uMhlanga Estuary on the KwaZulu-Natal coast a few years ago exposed their fragility, but also revealed powerful tools scientists are using to track damage, recovery, and the fight against pollution. Article by the Institute of Natural Resources and partners.

South African rivers and estuaries are under serious threat. As national water demand soars and water quality plummets in many parts of the country, the challenge of monitoring and protecting aquatic ecosystems becomes increasingly urgent. The manner in which the impacts of acute and chronic pollution on aquatic systems are managed and mitigated is critically important in maintaining and restoring impacted aquatic ecosystems. Field-based monitoring of pollution impacts and recovery, while important, is often difficult to implement due to high costs and limitations in capacity (in terms of the number of people with the required expertise) and capability (the degree of skills individual experts possess). So, when disaster strikes, how do we measure the damage and the recovery?

In 2021, a massive chemical spill near the uMhlanga Estuary on South Africa's East Coast presented both a tragedy and an opportunity. The spill devastated the estuarine ecosystem, killing fish, aquatic life, and riverside vegetation. In the wake of the event, researchers from the Institute of Natural Resources and the University of the Western Cape, along with their partners, sought answers: Which indicators are most effective in tracking pollution impacts and ecosystem recovery? The team received project funding from the UK Department for Environment, Food and Rural Affairs (DEFRA) through the Joint Nature Conservation Committee Environmental Pollution Programme.

What was measured and why it matters?

To establish what needed to be monitored and the value that this would offer to decision-making, the team compared the uMhlanga Estuary, heavily impacted by the spill, with two other estuaries of similar makeup: the uMdloti, affected by ongoing pollution but no acute event, and the iMpenjati, considered relatively pristine (Figure 1). The comparison allowed for a valuable, side-by-side look at how ecosystems respond to different types of stress, both sudden (episodic) and chronic.

For each river-estuary system assessed, water quality samples were collected to test for concentrations of agrochemicals, nutrients and related water quality parameters to detect the impacts of the spill and those of associated land uses for in the other two systems. For the biological monitoring, our study used the South African Scoring System 5 (SASS5) for macro-invertebrates and recognised diatom indices (which were also used by the professional teams to assess the response of the system to the mitigation measures by the polluter). SASS5 is a method of collecting and identifying aquatic macroinvertebrates from different biotopes.

The goal of SASS5 is to assign a score, such as the SASS score, number of taxa, and average score per taxa (ASPT), which gives an indication of the water quality (Figure 2). Diatom indices also assess water quality through microscopic algae known as diatoms, which are sensitive to pollution. We also included the use of the Fish Rapid Assessment Index (FRAI), which is South Africa's standard tool for a quick assessment of the ecological conditions of a river from its fish community (Figure 2), and remote sensing (satellite imagery) to understand the spatial impact of the spill on riparian vegetation over time.

Using this mix of water sampling, species surveys, and cutting-edge earth observation techniques, the team tracked a wide range of environmental indicators. The most useful of these indicators were those measured using remote sensing, satellite-based vegetation monitoring, as they proved most powerful for visualising large-scale impacts over time (Figure 3). Using indices such as NDVI (Normalized Difference Vegetation Index) and SAVI (Soil Adjusted Vegetation Index), researchers tracked changes in riparian vegetation from 2018 to 2024. The data told a clear story: Following the spill, vegetation health around uMhlanga plummeted and has yet to return to pre-spill levels, even three years on. Similar analyses in the iMpenjati and uMdloti estuaries helped confirm the devastating impacts of the spill on the system, but also pointed to the fact that the system was impacted by extreme weather events (floods, specifically) after the spill, and like most other estuaries in the region, is impacted by a variety of chronic pollution streams.

BACK TO TOP

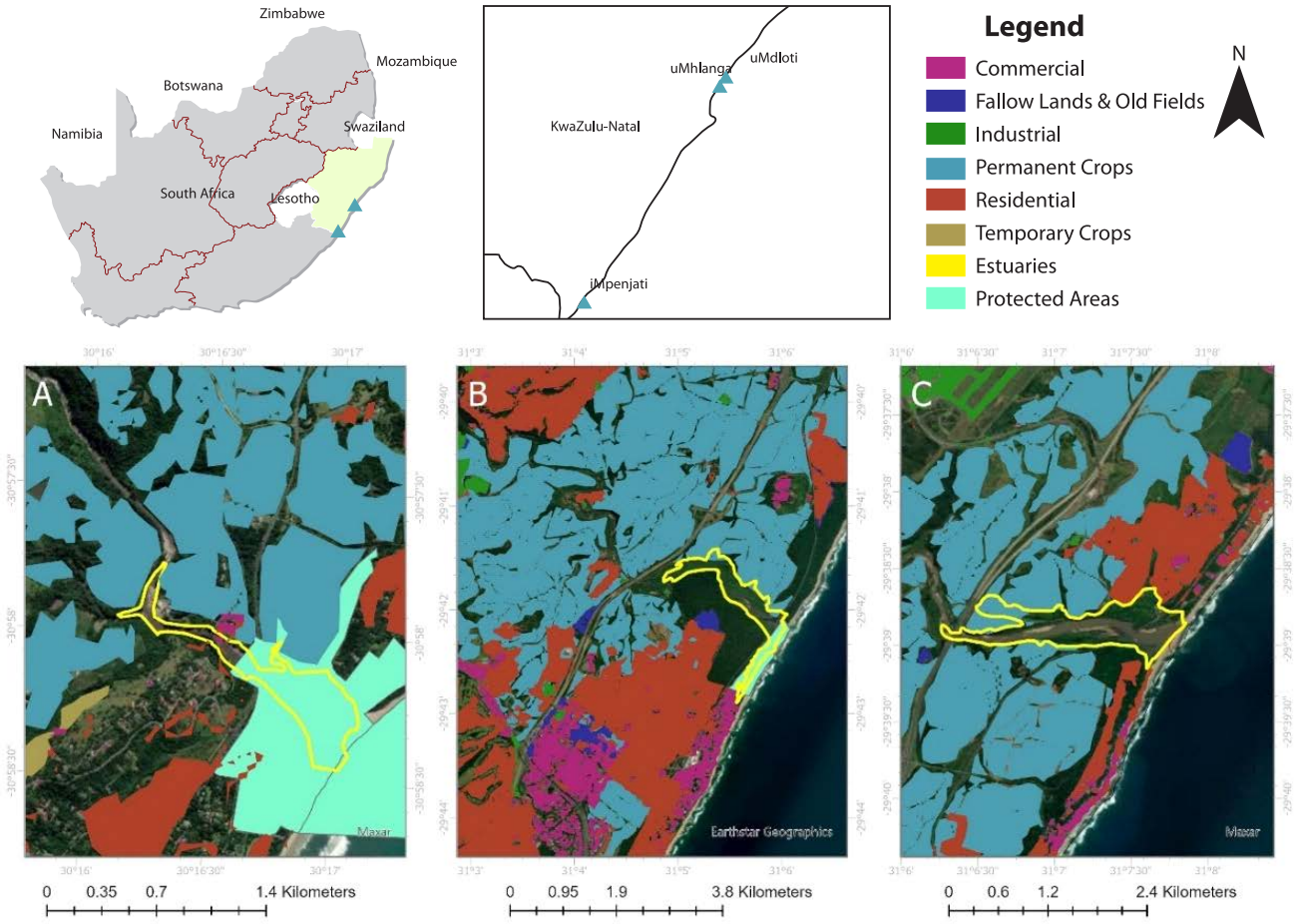


Figure 1: The locality of the three selected estuaries, iMpenjati (A), uMhlanga (B), and uMdloti (C), Estuaries and their associated land use for the present project, using land cover data from 2023.

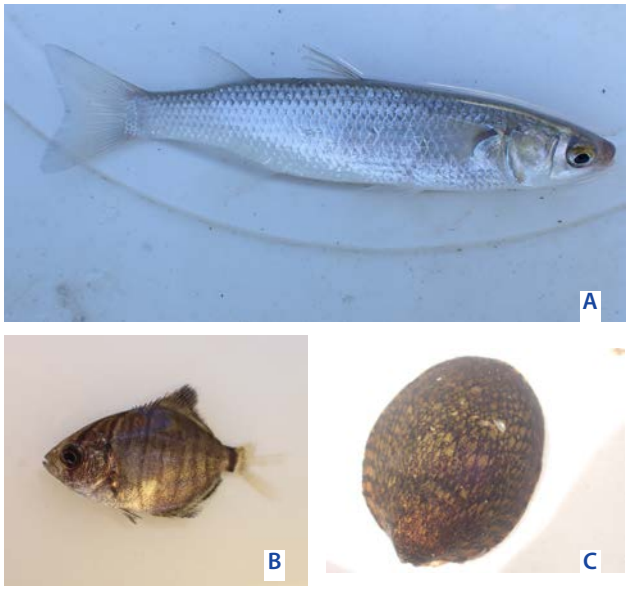


Figure 2: The freshwater mullet (A), a southern African endemic, and the oval moonfish (B) need healthy rivers and estuaries to complete their lifecycle and were found in the iMpenjati system with low abundances in the uMhlanga and uMdloti estuaries. A Septaria mollusc (C) that contributes to the macroinvertebrate health score for the freshwater systems.

One plant's story: The common reed as a pollution indicator

Using 'old-school' vegetation surveys (Figure 4), the team was also successful in showing that the common reed (***Phragmites australis***) could represent an unlikely hero in polluted estuaries. Its response to the spill, in the form of higher plant density but shorter stems, mirrored the satellite imagery and ground surveys, revealing how vegetation copes with recovery under stress. These results suggest it could be employed as a valuable indicator species for future pollution monitoring in wetland systems.

What the findings reveal

What is worrying, though, is that even after three years, the uMhlanga Estuary is still struggling. Surprisingly, the uMdloti, untouched by the chemical spill, showed similar levels of ecological degradation. This points to a sobering reality: Chronic pollution from sources like untreated sewage and failing infrastructure is just as damaging, and perhaps even more insidious. Fish populations in all three estuaries were also in poor condition, signalling deep systemic stress across these ecosystems.

The study showed that even though different tools provide different insights, all are needed. There is no silver bullet:

- SASS5 is practical and cost-effective for macroinvertebrate

BACK TO TOP

INR

Figure 3: Sentinel-2 satellite image of the uMhlanga estuary and surrounding areas before the spill event (A), the smoke plume during the warehouse damage (B), the impact of the spill (C) and system recovery after the spill (D). The red rectangle shows the overall area that was assessed by remote sensing techniques.

assessment of rivers.
- FRAI is essential for both river and estuary fish community assessment.
- Diatoms offer a longer-term view of pollution.
- Remote sensing gives a fast, affordable way to flag problem areas for closer inspection.

A call to action

This study tells a compelling story of science in action. It shows that South Africa has the tools to monitor estuarine health, but these are not being used proactively or consistently. Too often, biomonitoring is reactive, launched only after a disaster strikes (as in the case of the uMhlanga Estuary). We need ongoing, strategic monitoring to spot red flags before they escalate into crises, and data to inform policy and decision-making. Most of all, we need action. Government, business, scientists, and communities must come together to tackle pollution at its source. Monitoring is not enough without the will to act on what we learn.

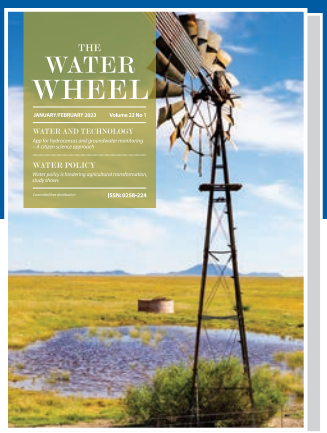
INR

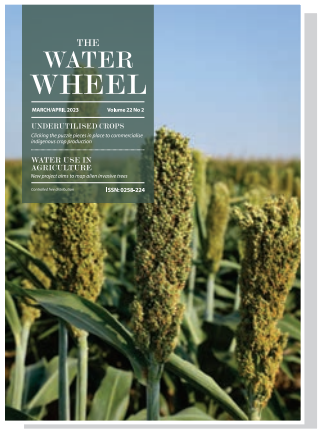
*Figure 4: Vegetation surveys around the common reed (*Phragmites australis*).*

BACK TO TOP

THE WATER WHEEL

SUBSCRIPTION





Contact Details

Name: _____

Company: _____

Designation: _____

Tel: _____

Fax: _____

E-mail: _____

What would your like to read more about in the Water Wheel?

_____

_____

_____

_____

WATER RESEARCH COMMISSION

The Water Wheel

Tel: +27 (0) 12 761-9300
E-mail: laniv@wrc.org.za /www.wrc.org.za
Physical address: Lynnwood Bridge Office Park, Bloukrans Building, 4 Daventry Street, Lynnwood Manor
Postal address: Private Bag X03, Gezina, 0031

BACK TO TOP

GROUNDWATER

Groundwater doesn't age like fine wine: Rethinking residence times in fractured rock aquifers

Dr Yazeed van Wyk unpacks the challenges around determining groundwater age in South Africa's fractured rock aquifers.

In groundwater research (hydrogeology), the term 'groundwater age' is frequently used as a proxy for the time elapsed since a water parcel infiltrated the subsurface and entered the groundwater system. While the term may serve as a useful conceptual approximation, its application in fractured and heterogeneous aquifer systems requires careful consideration.

Unlike a sealed bottle of wine, which follows a relatively predictable chemical evolution under controlled conditions, groundwater in fractured aquifers does not 'age' uniformly. Some water flows quickly through open fractures, while other portions linger in tiny rock pores for decades or centuries. As a result, a water sample from a borehole is rarely of one single age, but rather a blend of waters of many different ages. It flows through fractures and rock pores at variable rates, mixes continuously, and interacts chemically with the surrounding environment, making its residence times highly variable and far less predictable.

A useful way to think about this is like a shopping mall. The age of one shopper is the time they personally have spent inside since they entered. The mean residence time, however, is the average time that all shoppers spend in the mall. In groundwater, tracers such as carbon-14 can give us an apparent age of a water sample but because samples are mixtures, the apparent age is often closer to the mean residence time of that mixed water, rather than the true age of a single parcel. In such settings, the 'age' of groundwater is not a fixed value but better described as a distribution of residence times, of which the mean residence time is just one summary statistic. Recognising this variability is critical for accurate interpretation of tracer-based estimates and for the development of realistic conceptual and numerical models.

BACK TO TOP

This nuance is important in a country like South Africa, where fractured aquifers dominate, and groundwater remains a vital resource for both urban and rural populations. While isotope and tracer-based methods have become increasingly valuable tools for improving hydrogeological conceptual models, there are inherent limitations in oversimplifying age interpretations. Discussions at the International Atomic Energy Agency (IAEA) technical working group on environmental tracers, held in Vienna, Austria, in April, reinforced the growing consensus that mean residence times, full age distributions, and multi-tracer approaches provide more scientifically sound and informative insights than relying on just single age estimates alone.

For example, short-lived tracers such as ^{35}S and ^{222}Rn are increasingly used to delineate recent recharge and shallow flow paths, while noble gases (e.g., CFCs, SF_6, $^3H/^3He$) are employed to estimate apparent ages of younger groundwater components. These tracers operate under fundamentally different assumptions. Radio-sulphur isotopes, such as ^{35}S, produced via cosmic ray spallation of atmospheric argon, rapidly oxidise to sulphate and enter the water cycle via meteoric precipitation. Their relatively short half-life (87.4 days) makes them useful for identifying recharge events on seasonal to sub-annual scales.

In contrast, gas tracers such as $^3H/^3He$ only start the isotopic clock once water passes below the water table, thus missing residence times in the vadose zone where important biogeochemical processes occur. This is a critical point also raised during the Vienna meeting. Groundwater age, if interpreted solely from gas chronometers, does not capture the temporal domain of infiltration and vadose zone transport.

For fractured rock aquifers, where flow is often governed by both matrix diffusion and fracture advection, the vadose zone may represent a significant portion of the total transit time. Hence, combining isotopes that reflect vadose zone processes (e.g., stable water isotopes, ^{35}S) with those that reflect saturated zone residence (e.g., SF^6, CFCs) yields a more complete hydrochronological profile.

Fieldwork conducted at a now decommissioned quarry near Pretoria reinforced these insights. Environmental tracers, including stable isotopes (such as Deuterium, ^2H and Oxygen-18, ^{18}O) and the radioactive isotope Tritium (^3H), were applied to investigate recharge processes and groundwater flow dynamics. The stable isotopes provided information on recharge elevation and seasonality, while the presence of tritium (^3H) indicated the presence of modern water within the system. Combined, these tracers constrained mean residence times and highlighted the mixing of recent recharge with older groundwater components, a common feature in fractured quartzite aquifers.

In the broader tracer literature, additional tools such as artificial tracers (e.g., fluorescein, rhodamine WT), noble gases, and short-lived radionuclides (^{222}Rn, ^{226}Ra, $^{224}Ra/^{223}Ra$ ratios) have been used to delineate fracture-dominated flow and quantify residence times on the order of days to weeks. These approaches are particularly relevant in dynamic environments such as coastal lagoons or managed aquifer recharge systems, where short-term flushing and discharge processes dominate. The concept of an 'endmember' representing the unmixed, original groundwater signature prior to dilution or mixing is also critical in such studies.

Yet even defining a representative endmember is non-trivial, as an equilibrium between aquifer material and infiltrating water is not always reached, especially for sorbing tracers like radium. The time to reach equilibrium is strongly influenced by the distribution coefficient (K_D) and isotope half-life, ranging from minutes to days for ^{224}Ra ($t½ = 3.63$ days) and ^{223}Ra ($t½ = 11.43$ days**)**, to years for ^{228}Ra ($t½ = 5.75$ years), and up to millennia for ^{226}Ra ($t½ = 1600$ years). These can be converted into approximate flow distances based on groundwater velocity assumptions.

For communities in rural areas or small towns in the Karoo, knowing whether borehole water is 'young' or 'old' can mean the difference between safe drinking water and contamination risk. This is why, from a South African management perspective, these scientific insights carry real urgency. Fractured rock aquifers, which supply much of the country's water, are often assumed to be naturally protected by depth or by long mean residence times. Yet environmental tracer evidence shows that rapid preferential flow paths can deliver 'young' recharge water through fractures and faults into supposedly well-protected aquifers. This means that even boreholes yielding predominantly 'old' water may still be vulnerable to recent surface contamination if a small fraction of young water is present.

With pressures from urbanisation, agriculture, and climate variability mounting, these dynamics can no longer be ignored. Effective groundwater management must therefore go beyond bulk averages and explicitly account for the youngest fractions of water, which act as sentinels of vulnerability. This requires clearer science communication. Terms such as 'groundwater age' must be unpacked, and mean residence time framed as a statistical simplification of a much broader distribution of travel times.

What is urgently needed is the routine application of multi-tracer frameworks, tailored to site-specific conditions, that capture the full range of transit times, geochemical interactions, and hydrological domains traversed by groundwater. The Vienna technical meeting strongly advocated for this integrative approach, and adopting it in South Africa would provide a more realistic foundation for recharge protection strategies, contamination risk assessment, and long-term water security.

Finally, building global inclusivity in tracer research is critical. The Global South, despite bearing a disproportionately high share of groundwater dependence, remains underrepresented in method development and capacity building. Platforms such as the IAEA meeting play a key role in sharing data, harmonising protocols, and fostering collaborative learning.

In conclusion, as highlighted throughout this article, groundwater does not 'age' like fine wine. It flows, mixes, and evolves in response to geological, climatic, and anthropogenic drivers. In South Africa, where fractured-rock aquifers supply much of the population's water, these dynamics have immediate implications for recharge protection, contamination risk, and sustainable water management. Scientific tools and approaches must reflect this complexity. By embracing multi-tracer methods, refining conceptual models, and communicating findings clearly, groundwater assessments can become not only more accurate but also better aligned with the practical challenges of managing South Africa's vital water resources.

DEEPLY ROOTED IN SOUTH AFRICA WATER SOCIETY

www.wrc.org.za

The Water Research Commission not only endeavours to ensure that its commissioned research remains real and relevant to the country's water scene, but that the knowledge generated from this research contributes positively to uplifting South African communities, reducing inequality and growing our economy while safeguarding our natural resources. The WRC supports sustainable development through research funding, knowledge creation and dissemination.

The knowledge generated by the WRC generates new products and services for economic development, it informs policy and decision making, it provides sustainable development solutions, it contributes to transformation and redress, it empowers communities and it leads various dialogues in the water and science sectors.

The WRC Vision is to have highly informed water decision-making through science and technology at all levels, in all stakeholder groups, in innovative water solutions through research and development for South Africa, Africa and the world.

FOLLOW US ON

WATER RESEARCH COMMISSION

THE POWER OF KNOWLEDGE TO THE PEOPLE