THE WATER WHEEL

November/December 2019 Volume 18 No 6

ESTUARIES

Fisheries in South African estuaries – Are we on the right road?

WEATHER FORECASTING

Gough: The remote island that all South Africans depend on

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WATER RESEARCH COMMISSION

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South Africa's aquatic nurseries are under threat, evidence shows. See the article on page 12.

FLUID THOUGHTS

WRC CEO, Dhesigen Naidoo

Future-proofing food security in a hotter, drier world

We are in the middle of a South African heatwave.

The Northern Hemisphere has just completed a very uncomfortable summer, with July 2019 being the hottest July in recorded history. The start of the Southern Hemisphere spring appears to be completing the 2019 weather cycle in competition with the North – promising a hot, dry summer with intervals of short, intense rainfall spells. In other words, more threats to our food security.

In the midst of this, World Food Day 2019, celebrated on 15 October, continued to leave us uncomfortable. While considerable progress has been made in various parts of the world, we still have 821 million people that suffer from chronic undernourishment. That's more than 10% of the world's population. The number for South Africa, according to Statistics South Africa, is 6.8 million people that are chronically hungry, that is going to bed on an empty stomach daily. In this mix are the 500 000 households with children that are subject to these same hunger pangs. We add to this the growing global epidemic of obesity and malnutrition to complete the ticking time-bomb of the global nutrition challenge of the 21st century.

We also know that undernutrition is a central pillar of the poverty trap. Poverty restricts access to food. This leads to restricted development both physically and cognitively. This is super-critical in the first 90 days of a child's life and in general if this persists for the first 4 years – the damage is largely irreversible. This, in turn, limits economic activity and productivity which perpetuates the poverty, and the cycle continues inter-generationally. The outlook is dimmed by the prospect of an even more difficult environment on the back of climate change and increased frequency of extreme weather events like droughts and floods. How do we organise for future food security to enable the next generation to successfully escape the poverty trap in South Africa and the world?

The key engines to future proof food security include the following. First is the toolbox of the 4th Industrial Revolution (4IR). Higher levels of computation and artificial intelligence enable the old dream of precision agriculture. Optimally using key resources like water, energy, fertilizers and other growth enablers on the back of better more accessible real-time information to drive efficient agriculture and higher productivity. An important anxiety associated with these interventions is automation, and the potential negative impact that it will have on jobs and livelihoods.

4IR can, in fact, stimulate and achieve exactly the opposite. Currently, 70% of the world's food is produced by 500 million small-scale farmers. Mobile technology tools will enable these 500 million farmers to have a reasonable component of real-time information to perform state-of-the-art precision agriculture on the smallest of plots – increasing productivity and drastically reducing costs.

Secondly, with the advent of new innovations, such as the concept of social franchising, can double the number of small-scale farmers and therefore agricultural productivity in the next ten years globally. Social franchising has been successfully piloted by the Water Research Commission (WRC) and is a new model for enterprise development where someone can become with a zero financial investment with access to a support structure for an initial period.

The WRC pilot has created 20 companies, each now employing at least three people and still in business three years on. This may be a viable mechanism for emerging farmers in South Africa and means to achieve a global target of 1 billion small-scale farmers and many more entrepreneurs in the food value chain.

However, these interventions may prove ineffective against the vagaries of heatwaves and extreme weather events catalysed by climate change. There is also the matter of the obesity and malnutrition epidemic. Key to food security resilience in diversity of staples. If these new staple crops have the added benefits of higher nutrition levels and greater tolerance to drier conditions, then we truly have a winning solution.

The third intervention is thus underutilised and orphan crops. They are sometimes also referred to as traditional crops, because our wise ancestors had an important handle on food security, albeit on a smaller scale, and are in most cases indigenous. Research has shown that in general they use much less water than their exotic mainstream monoculture cousins – making them more resilient to drought conditions. They are also more nutritious with higher levels of iron and trace elements, becoming an important bastion against malnutrition. Examples include well known sweet potato, Bambara groundnut, cowpeas,

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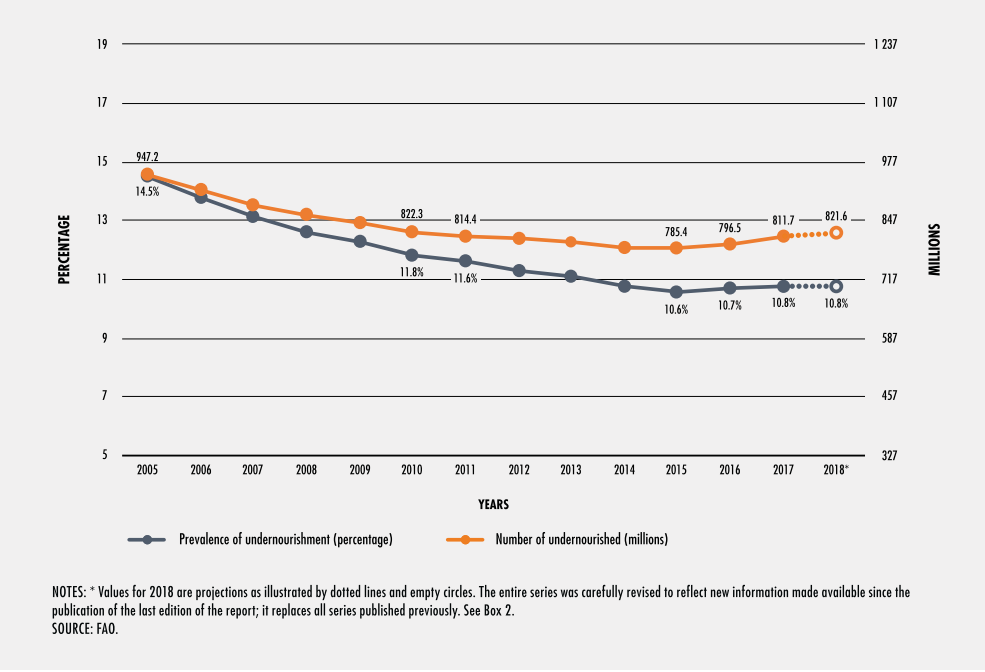
spider plant and indigenous spinach – amaranthus or morogo. The super-resilient include sorghum, which is both drought tolerant as well as tolerant to waterlogging.

The Green Revolution of the 1950s and 1960s massified agriculture in a mono-culture paradigm to stave off mass hunger and was very successful. The 21st century agricultural revolution lies in a new diversification in a resource efficient and resilient agricultural model enabled by the innovations of the 4th industrial revolution.



NOTES: * Values for 2018 are projections as illustrated by dotted lines and empty circles. The entire series was carefully revised to reflect new information made available since the publication of the last edition of the report; it replaces all series published previously. See Box 2.
SOURCE: FAO.

The number of undernourished people in the world has been on the rise since 2015, and is back to levels seen in 2010/11. Source: FAO

WATER DIARY

Water and development
1-5 December
The International Water Association (IWA) is hosting its Water and Development Congress & Exhibition in Colombo, Sri Lanka.
Visit: www.waterdevelopmentcongress.org

Small water systems
1-5 December
The 16th International Specialised Conference on Small Water and Wastewater Systems will be held in Murdoch, Australia.
Visit: www.swws2019.com

Water governance
11-13 February 2020
The Water Institute of Southern Africa (WISA) is offering a three-day training course in Stellenbosch on water governance. The course has been designed to facilitate understanding of the principles of water governance from a human rights perspective, and covers international water governance approaches, sustainable water resource management initiatives, and the implementation of measures in South Africa through the relevant legislation.
Visit: www.wisa.rog.za

Sanitation
21-24 July 2020
The First IWA Non-Sewered Sanitation specialist group conference is being hosted at the Future Africa Campus in Pretoria in partnership with the Water Research Commission and the University of Pretoria. The aim of the conference is to provide stimulus for research and innovation for non-sewered sanitation and off-grid sanitation solutions, including faecal sludge management, build the technical and scientific base for sanitation and to contribute to scientific knowledge and good practice learnings. *Enquiries: Dr Sudhir Pillay, Email: sudhirp@wrc.org.za, Visit: www.shorturl.at/DIJQ0*

World Water
18-23 October 2020
The IWA World Water Congress will take place in Copenhagen, Denmark with the theme 'Water for smart liveable cities'.
Visit: https://worldwatercongress.org/

Municipal water
28-30 October 2020
The Institute of Municipal Engineering of Southern Africa will be holding its annual conference in Cape Town.
Visit: https://www.imesa.org.za/

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NEWS

Efforts to clamp down on pollution in Knysna

Authorities in Knysna have begun a drive to tackle pollution threatening the Knysna estuary.

Positive, proactive engagements are underway by various stakeholders forming part of the Knysna Authorities Pollution Committee. Among others, nutrients in the wastewater treatment works effluent – including ammonia, pH level, nitrates, suspended solids and chlorine – are being monitored closely.

Park Manager for Knysna, Megan Taplin, said: "High readings of ammonia are a concern for South African National Parks (SANParks) for the survival of both plant and animal life in the estuary." She adds that the SANParks team is working with their partners to do more than just sample for E.coli in the Knysna estuary, but monitoring all potential polluters.

"Our partnership with the municipality allows monitoring of solid waste and systems leading to the wastewater treatment works. Oil and grease influx to the works and sewer system is also being monitoring by the municipality," she added.

There is evidence of high loads of oil entering the system and ending up at the wastewater treatment works. Authorities are ramping up efforts to find the source(s) of the oil along the networks. "If we can determine the trends of when the oil and grease enter the wastewater treatment works..it might make it easier to track the polluter," noted Knysna Municipality Technical Director, Pravir Hariparsad.

A positive move is the number of interventions planned for the estuary, including the planned appointment of a freshwater specialist by the municipality. The specialist will assess the Bongani River system from source to sea.

Source: SANParks

High spring temperatures negatively impacting South Africa's water

The recent high temperatures being experienced over large parts of South Africa are having a negative impact on South Africa's dam levels, according to the Department of Water and Sanitation (DWS).

A weekly report by the DWS shows that as a result of sweltering temperatures, dam levels are dropping at an average 1% week-on-week. Comparatively, dam levels have dropped 10%, from 74% to 64% compared to the same period last year.

Even more alarming is the water situation in Limpopo and the Eastern Cape where dam levels had dropped to almost half of where they were in 2018, the department reported in October. According to Dr Chris Moseki, Specialist Scientist in the DWS, scientific projections are that hot temperatures will persist until the end of summer next year. Between October and December the country will experience below-average rains that will be accompanied by hot temperatures that will continue to raise evaporation levels in dams.

However, the South African Weather Service (SAWS) predicts that between mid-December and February next year the major parts of the country may receive heavy rains, which may lead to flash floods.

"Key to the water situation is the responsibility of South Africans to use water wisely and sparingly. We must move away from the dogma that water is the government's responsibility alone," noted Dr Moseki.

Against this background, the DWS has renewed the call to all South Africans to intensify their water conservation efforts.

Source: DWS

eThekwini climate plan lauded by African mayors

Ethekwini Municipality has been lauded by mayors attending the C40 World Mayor's Summit in Copenhagen in October for being the first city in Africa to develop the Climate Action Plan aimed at reducing carbon emissions.

Tabling the plan at the pre-summit meeting of African Mayors, eThekwini Municipality Mayor and Vice Chairperson for Africa, Mxolisi Kaunda, said that the plan will go a long way towards creating a climate resilient and carbon neutral city.

In response to the Paris Agreement, the plan seeks to accelerate the action required to limit temperature increase to 1.5 °C, which is vital to avoid catastrophic impacts facing vulnerable communities. It also comprises 33 actions and 149 sub-actions aligned to nine thematic areas that provide a pathway for Durban to achieve climate resilience and carbon neutrality.

According to the plan, by 2030, Durban will have achieved a 40% reduction in emissions and a 80% reduction in emissions by 2050.

"Recently, eThekwini Municipality experienced devastating floods. This was an indication that the business-as-usual approach on climate change was no longer an option, and we needed to do things differently. We are pleased that this plan responds precisely to the challenges that we are facing," said Kaunda.

During his address at the African Mayors and Delegates Dialogue, Kaunda thanked the mayors for taking the initiative to address climate change in Africa in a manner that is relevant for the African context.

"As African leaders, we always advocate for African solutions to African problems. From the discussions we have had, it is clear that if C40 work is to succeed in Africa we must, among others, integrate inclusivity and resilience in our work, recognising that vulnerable communities in Africa bear the brunt of climate-related disasters. Therefore, let us work as a collective to accelerate the transition to resilient and carbon neutral cities," noted Kaunda.

The mayors of Accra, Tshwane, Johannesburg, Lagos and Abijan commended eThekwini for leading the way, adding that with the appointment of Kaunda as Vice Chairperson for Africa, eThekwini will be in a better position to provide guidance to other municipalities on the continent.

Study shows community groundwater to be unfit for drinking

South African research and development organisation, the CSIR, is working with the community of Stinkwater in Hammanskraal, outside Pretoria, to improve the quality of ground and surface water in the area.

The organisation recently concluded a three-year project aimed at investigating the health risks that untreated groundwater poses to the user community and to explore potential interventions. "People need clean water to consume, irrigate, for livestock, etc. but water is a luxury many do not have access to," said CSIR Senior Scientist and Laboratory Manager, Wouter le Roux.

The community of Stinkwater has no access to piped water distributions and rely on water delivered by municipal trucks. Often, this is not enough. Le Roux explains that the community has found its own solution to accessing water through hand dug wells. This untreated water is then used by the community, exposing them to various health risks.

A total of 144 water samples were collected over a two-year period over the wet and dry seasons, and the majority of samples were taken from hand-dug wells.

The study found that fluoride exceeded the drinking water standard in 9% of samples (max 3.6 mg/L), while nitrate exceeded the drinking water standard in 87% of samples [Average 23.1 mg/L). ***E.coli*** bacteria, which is used as an indicator of faecal pollution, was also detected in the majority of samples.

Le Roux said the CSIR was looking at ways to use nano-engineered clays and plants to remove nitrate from the water, rendering it safer for consumption.

Source: CSIR

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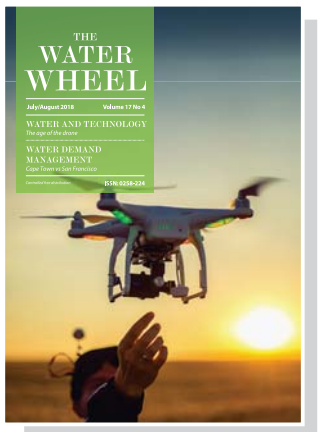

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NEW WRC REPORTS

Determining the water footprints of selected field and forage crops, and derived products in South Africa

This research has addressed important issues in agricultural sustainability and human survival as a whole in South Africa. The research established country-specific standardised procedures for calculating blue and green water footprints for irrigated field and forage crops, and this can contribute towards the setting of accurate benchmarks for freshwater use along the lifecycle of crops. The research has linked the water footprint applications to economic and social analytical tools. The inclusion of the social and economic impacts of proposed changes in water use behaviour provides details insights and understanding of water management. The analysis of consumer awareness, preference and willingness to pay for water footprint information on product labels gives insight into the scope for incentivising water users through price premiums to use freshwater efficiently.

Report no. 2397/1/19

WET-RehabEvaluate Version 2: An integrated monitoring and evaluation framework to assess wetland rehabilitation in South Africa

WET-RehabEvaluate was developed as a framework to guide the application of monitoring and evaluation during wetland rehabilitation projects, but further experience and recent research have identified several potential improvements required for evaluating wetland rehabilitation efforts. In an attempt to capture these improvements, the Water Research Commission (WRC) research project sought to compile a framework that is a user-friendly guide for implementing monitoring and evaluation for wetland rehabilitation in South Africa. WET-RehabEvaluate was used as the starting point for the improved framework, although significant changes were incorporated to address identified shortfalls. Once a draft framework was compiled, which reflected recent experience and research, it was assessed through an iterative process that applied the framework (or parts thereof) to eleven cases during a research process. Lessons learnt after each application were fed back into the framework development process.

Report no. 2344/1/19

Urban groundwater development and management

Groundwater use by urban areas urgently needs to shift from lack of active management of groundwater and indirect use (of groundwater's assimilative capacity) with negative implications, to active management leading to the potential for bulk water supply from urban groundwater resources. In cases where urban groundwater will not be used for bulk supply for whatever reason, active management of the urban groundwater is still required to protect the resource for other uses (ecological services, garden irrigation, food gardens). Contributing to this shift is the core motivation for this project, which was to: understand the status quo of urban groundwater development and management in South Africa; compare these to best practice for urban groundwater management; and develop position papers and a tactical plan to address the gaps.

Report no. 2741/1/19

An investigation to determine if South African coal mine pitlakes are a viable closure option

South Africa has been mining coal since the early 1800s. Opencast coal mines generally leave a final void as a consequence of the mining method. Once mining operations cease, these voids fill with water forming a lake which is generally referred to as a 'pitlake'. It is estimated that there are over 200 pitlakes in the three major South African coal fields. The study evaluated the environmental sustainability of using pitlakes as a closure option for new and proposed coal mines in South Africa. The investigation concentrated on the two major drivers of pitlake sustainability, while investigating four different pitlakes:

- The Mafutha pitlake and stand-alone pitlake in the Waterberg coalfield
- The Kriel and Kleinfontein pitlakes are associated with opencast operations and in direct hydraulic contact with backfilled material both located in the Witbank/ Mpumalanga coalfield
- The Rooikop pitlake which is hydraulically connected with both opencast and underground operations located in the KwaZulu-Natal coalfield.

These pitlakes were selected on the basis that they are representative of the major South African coalfields considering variances in geology and climatic conditions. Also available as part of this study is the publication, ***A preliminary manual for the design of coal mine pitlakes as an environmentally stable closure option in South African mines*** (**WRC Report no. TT 797/2/19**)

Report no. TT 797/1/19

Seamless forecasting of rainfall of temperature for adaptation of farming practices to climate variability

Agriculture is highly sensitive to climatic parameters, and numerous studies show that Africa will be highly affected by long-term climate changes, mostly in a negative manner. Adaption is thus required. In addition to the exploration of long-term adaptation strategies in response to climate change, there is a demand for shorter time-scale coping mechanisms, which would make agricultural systems more resilient in the face of climate variability (vs climate change). This research focused on harnessing seasonal forecasts and impact models' numerical capacity to better prepare agricultural activities to climate variability

Report no. 2496/1/19 (Volume 1 – Seasonal forecasts and smallholders), 2496/2/19 (Volume 2 – Seamless forecasts and sugarcane)

To download a free copy of these reports Visit: www.wrc.org.za.

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SUCCESSFUL SYMPOSIUM UNITES WATER SECTOR

In September 2019, the Water Research Commission (WRC) held its 4th Symposium titled 'Innovation in every drop'.

Key stakeholders, including award-winning scientists, ground-breaking innovators, renowned academics, policymakers, international development organisations, donor institutions, politicians, and private sector representatives attended. The message was that the world is on a precipice.

Water is necessary for the survival of life on earth, and earth itself. It is linked to every facet of life and economic activity. Nevertheless, 1 billion people are water insecure and water scarcity is one of the greatest human challenges of the 21st century. Population growth, pollution, and climate change are threatening the sustainability of the world's water resources. Data from the World Resource Institute show that approximately 80% of countries are already experiencing high, to extremely high, water stress.

UNICEF estimates 2.1 billion people lack safe water at home, and 4.5 billion do not have toilets at home. According to the UN an estimated 80% of wastewater (i.e. faecal sludge from toilets) worldwide is released into the environment without treatment. In developing countries, 95% of wastewater is released into the environment untreated.

In South Africa, the availability of water of acceptable quality is predicted to become the single greatest development constraint. Population growth (currently at 50 million and growing) and rapid rates of urbanization (estimates are that by 2030, 71% of the South African population will be living in urban areas) exacerbate the crisis. Coupled with the increasing frequency of droughts resulting from climate change, demand for water will soon outstrip supply. This will result in insufficient water for food production and normal household use. It also means that there will not be enough water to expand or maintain SA's current waterborne sanitation infrastructure (i.e. flush toilets and sewerage pipes).

The experts also explained that current municipal wastewater management systems have not been maintained and are starting to fail.

Further, 15% of the South African population still do not have access to adequate sanitation. Among those counted as having access to "adequate sanitation" are the millions in informal settlements and rural areas who use VIP toilets (i.e. pit latrines) that (in many cases) are not being emptied, or where there are no facilities to dispose of the faeces in an environmentally friendly and safe way. At present, 45% of South Africa's river systems and 60% of wetlands are critically endangered, and there is extensive biodiversity loss. Water quality is further decreased by the increasing presence of emerging contaminations like pharmaceuticals (e.g. ARVs, hormones), treatment resistant bacteria and genes, microplastics, and endocrine disrupting compounds (EDCs) in our water.

The questions that come to mind are: Can we still save ourselves and the planet? If so, how?

The good news is that opportunities to change the negative global trajectory exist. When coupled with scientific research, innovation, and good governance, we can solve the problem by using our faeces and urine as resources rather than waste.

This approach is known as the sanitation circular economy. According to the Toilet Board Coalition (TBC) "the new sanitation economy presents vast potential for global economic growth, while addressing one of the most urgent challenges of our time, notably achieving access to improved safely-managed sanitation. It monetises toilet provision, products and services, biological resources, data and information, to provide benefits across the economy and society".

In layman's terms, the sanitation circular economy uses technology and innovation (e.g. self-cleaning toilets) to shift the responsibility for sanitation services away from national public sector entities and waterborne systems (i.e. sewage pipes and wastewater management), to local level and community-based off-grid systems and products, provided by small- or large private sector companies. The faecal sludge is used to produce resources such as biogas, bricks, fertilizer, nutrients, animal feed and oil. Sensors in your toilet can also be used to monitor your health.

Sanitation thus becomes a mainstream business, and the toilet a delivery system. Waste becomes a wealth and energy generating resource that increases as the population increases. Empirical evidence and business cases demonstrate that the approach is feasible. TBC studies have estimated that the value of the sanitation economy in India alone, will be $62 billion by 2021.

Internationally, the Bill and Melinda Gates Foundation has played a key role in promoting and supporting the research and innovation required for the circular sanitation economy. The Foundation is perhaps most well-known for its Reinvent the Toilet Programme. The reinvented toilet is a modular, transformative technology that offers a non-sewered sanitation solution, eliminating the need for a piped collection system. The aim of the reinvented toilet is to destroy all pathogens onsite and recover valuable resources; operate without sewer, water or electricity connections; and cost less than $0.50/user/day in a sustainable business model. The programme was catalytic in generating technological solutions, business models and research and livelihood opportunities. The Foundation also facilitates relationships between private sector companies (e.g.

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manufacturers and distributers) and innovators and scientists, to commercialise the innovations.

There are also South African initiatives to promote the sanitation circular economy. The Sanitation Technology Evaluation Programme was established to pilot and demonstrate innovative sanitation technologies in SA. Some innovations showcased at the Symposium include:

A "urine harvesting" that uses urine to produce bio-bricks that are stronger than commercial bricks are suitable in all environments.

Gender-sensitive urinals that separate the urine for use in the production of nutrients for agricultural production.

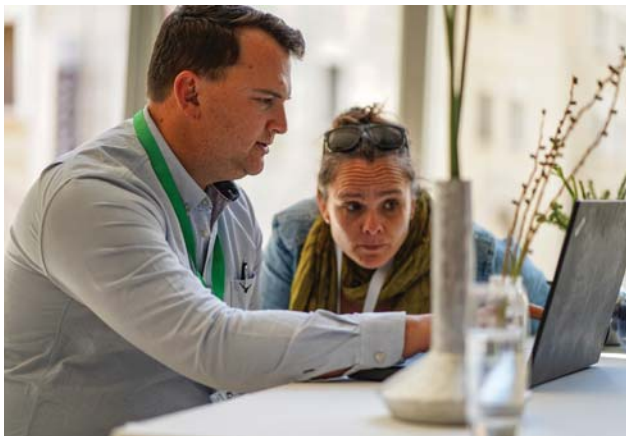
An online "sludge application rate advisor for agricultural use". Farmers use the online interface determine what, where, and how to use municipal sludge correct for their location, crop type, soil type, nutrient content, scale, and sludge source. It includes a cost-benefit analysis comparing the use of commercial fertilizer to municipal sludge.

Pour flush toilets combine the benefits and avoids the disadvantages of flush and VIP toilets. These off-grid, cost-effective toilets are placed inside a house and use less than three litres of water per flush.

The V-Cistern 3 litre flush toilet comes with a fitted handwash basin and uses the grey water from the hand basin for flushing.

These (and other) technologies actualize the WRC concept of "innovation in every drop". They are the core components of the sanitation circular economy and can have a positive effect on a range of areas including global economic growth, local livelihoods and unemployment, poverty, health, human dignity, energy production and, ultimately, save ourselves and the planet.

The WRC symposium was well attended throughout.



Collaboration was one of the main themes of the symposium.

Winners of the WRC Knowledge Tree awards with WRC CEO, Dhesigen Naidoo.

ESTUARIES

Fisheries in South African estuaries – Are we on the right road?

The fishes inhabiting our estuaries are under threat, but there is a way forward. Article by Alan Whitfield, Steve Lamberth, Paul Cowley and Bruce Mann.

©Alan Whitfield

Wise management by SANParks and Cape Nature of the Wilderness, Swartvlei and Goukamma estuaries is promoting the conservation of fishes along this section of the Cape south coast.

An estuary is a place where the river meets the sea. On a per unit area basis, estuaries are one of the most productive aquatic ecosystems on the planet. Because they are dependent on river water to bring them essential nutrients to maintain this high productivity, altered inputs can lead to a major disruption of the estuarine food web and therefore negative consequences for the associated invertebrates, fishes, birds and people. Scientific research in South Africa and elsewhere has also shown that estuaries are very important nursery areas for a wide variety of shrimps, prawns, crabs and fishes, and which we utilise as important protein resources from these systems.

Average human population densities in the coastal zone around the world are approximately three times higher than the average density over all land areas. Despite the concentration of people in the interior of South Africa, mainly due to the location of rich mineral resources in this region, coastal areas on the subcontinent provide attractive places to live, work and play for about 40% of our population. Many of the world's largest cities such as New York, London, Lagos, Mumbai and Sydney are situated on estuaries, with Richards Bay, Durban, East London and Port Elizabeth also being located on the banks of estuaries. In addition, many global towns, such as those dotted along the KwaZulu-Natal north and south coasts, are also located and have developed adjacent to such systems.

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The attraction of estuaries to humans stems not only from their natural beauty, which promotes settlement, but also the access to adjacent river catchments for freshwater and agricultural produce – as well as providing a diversity of habitats for recreational activities such as fishing, boating, sailing, canoeing, swimming, bird watching or just plain relaxation. Indeed, the attraction of estuaries is so great that we have even built marinas adjacent to some systems.

The question then arises – how well are we looking after our estuaries? Given that these systems have sometimes been described as the 'jewels' or 'honey pots' of the coastal zone, one would assume that they have been prioritised for conservation and management attention. However, a broad assessment of their management status in South Africa reveals that there have been steps in both a forward and backward direction in terms of addressing the protection and welfare of these valuable ecosystems. For example, the development of Estuary Management Plans by the Department of Environment, Forestry and Fisheries (DEFF) in collaboration with the CSIR and implementation by provincial authorities is to be highly commended. The implementation of these plans, however, still requires that management agencies are resourced with sufficient capacity and funding to implement the strategy and enforce regulations.

Similarly, the promulgation of the National Environmental Management: Biodiversity Act (NEM:BA) should have provided some protection for overexploited estuary-associated fish species such as dusky kob and white steenbras – instead we have seen increasing pressures being placed on these species by the growing lack of coastal fisheries law enforcement and the opening up of parts of existing Marine Protected Areas (MPAs) to fishing, e.g. the Mbhashe Estuary in the Dwesa Nature Reserve where fishing effort inside the reserve is now five times that outside the reserve. According to the Estuaries section of the latest National Biodiversity Assessment (NBA), illegal gill net fisheries account for more than half of the 3 700 tonnes of fish harvested annually from South African estuaries.

When the original Marine Protected Areas along the South African coast were declared, starting with the Tsitsikamma MPA in 1964, little or no attention was paid to estuaries – despite

©Alan Whitfield

The small but exceptionally beautiful temporarily closed Mendu Estuary in the Dwesa Nature Reserve was recently opened up to fishing. Estuaries where fishing is not permitted are urgently required at intervals along the South African coastline to allow overexploited fish stocks to recover.

©Nicolette Forbes

Part of a fish kill in the temporarily closed uMdloti Estuary caused by waters becoming oxygen depleted due to an oversupply of decomposing organic matter that was indirectly linked to excessive nutrient inputs from the river into the estuary. Increasing numbers of fishes in our estuaries are now also dying from pathogens introduced mainly by upstream aquaculture operations and the aquarium trade.

their role as important nursery areas for a number of marine fish species. Even recent proclamations by the DEFF have tended to ignore the need for Estuarine Protected Area (EPAs) and placed emphasis on new coastal and offshore MPAs instead. However, the great success of the Stilbaai Marine Protected Area, that includes the Goukou Estuary as a no-take area, provides an excellent example of what works for the recovery of targeted estuary-associated fish species.

Additional regulations for the protection and recovery of heavily exploited marine fishes, such as dusky kob, white steenbras, spotted grunter, leervis/garrick, tropical/Natal stumpnose and estuarine perch have been approved by DEFF. However, only by implementing these regulations will we be able to reverse the downward trend in the catches of these species. Indeed, our scientists have shown that all of the above targeted fishes are now less than 25% of their original adult stock size and still declining! Although recreational and subsistence fishers will individually deny any responsibility for the overexploitation, their collective impact is clear – these species are in crisis and currently common fish such as the temperate/Cape stumpnose are also beginning to show signs of significant declines in abundance.

Overexploitation of estuarine natural resources is not the only reason for the decline in condition of many estuaries on the subcontinent. Poor catchment management that is often associated with high soil erosion rates, and excessive freshwater extraction in some systems for irrigation (which results in little or no river flow reaching estuaries for extended periods), are major problems for certain estuaries. Less important at present but likely to become a major problem in the near future is environmental pollution, especially organic and inorganic wastes from agricultural, industrial and domestic sources. Water pollution caused by defective sewage processing plants in coastal towns and cities is also having a huge impact on declining water quality in our estuaries – which affects all living creatures associated with these environments, including ourselves.

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Dusky kob shown here are targeted by both recreational and subsistence anglers in estuaries, significantly declining in both average size and number as a result of decades of overfishing and, more recently, widespread environmental degradation. The average size of dusky kob from illegal gill nets recovered in KwaZulu-Natal estuaries is now only 30 cm, whereas this species becomes mature at 1 m in length.

Although excellent legislation exists to prevent pollution from entering rivers and estuaries, there are disturbing signs that the implementation of that legislation is being compromised by a number of factors, including the lack of maintenance of sewage processing plants by municipalities, inadequate financial resources in environmental law enforcement agencies, and the shortage of skilled human resources to document and prosecute parties guilty of environmental degradation. The increasing levels of metals and persistent organic pollutants (POPs) in the flesh of fishes from certain estuaries, which has led to local authorities such as eThekweni Municipality recommending a fish consumption of less than 200 g per month of fish captured in Durban Bay, is not the way to go.

Heavy rains in KwaZulu-Natal during early 2019 have highlighted the massive waste plastic loads that are carried into our estuaries and the sea. Although a superficial solution may be to remove the large plastic items and megaplastic fragments for recycling, increasing evidence is showing that microplastics, which cannot be easily recovered from the environment, are becoming incorporated into aquatic food chains. Thus, everything from small invertebrates and shrimps, to prawns and fishes that we consume are eating microplastics and, in effect, putting pollution on our plates!

There is, however, good news relating to these jewels in our coastal crown. South Africa has 290 estuaries, including the large Lake St Lucia system which is a designated Ramsar and World Heritage Site. Indeed, St Lucia on its own accounts for approximately 50% of the estuarine area in South Africa and is also one of the largest estuaries in Africa. This system is in the process of being rehabilitated by the iSimangaliso Wetland Park Authority after the devastating consequences of the removal and canalisation of the Mfolozi Swamps in the 1950s and the separation of the Mfolozi River from the St Lucia Estuary for more than half a century. If the system receives excellent summer rains in 2019/20 we may once again see a fully functional St Lucia Estuary and vibrant lake system contributing as a major fish and prawn nursery area for a variety of important commercial, recreational and subsistence coastal fishery species.

Although only 1% of South Africa's estuarine area is well protected, several unprotected estuarine types (from a fish perspective) could be transferred to the well protected category simply by improving fishery management and water quality issues. For example, according to the recent NBA Report on Estuaries, 32% of South Africa's estuaries and 10% of the total estuarine area could be categorised as well protected if fishing effort in just three estuaries (Kosi, Knysna and Langebaan) was better controlled.

Fortunately, there are some near pristine estuaries in the more remote parts of the Eastern and Western Cape Province – but growing human populations, especially in the former area, will inevitably place increasing pressures on the biodiversity, productivity and viability of these few remaining estuarine 'gems'. We therefore need to grasp the present window of opportunity to declare new EPAs that will be made accessible to people for non-destructive and non-consumptive recreational and ecotourist activities and, at the same time, ensure sustained prawn, crab and fish production for the future.

Scientific research in estuaries over the past half century, and especially during the last three decades, has unequivocally shown that our fish stocks are declining rapidly, mainly due to overfishing but also linked to increasing environmental degradation. The latest NBA Assessment Report for South African estuaries indicates that more than 63% of the estuarine area in the country is heavily or critically modified, with important ecological processes under severe pressure. According to the above report, compiled by leading South African estuarine scientists, this trend has negative consequences for coastal productivity, fisheries livelihoods, food security, property values and recreational enjoyment.

"Illegal gill net fisheries account for more than half of the 3 700 tonnes of fish harvested annually from South African estuaries."

In summary, we are faced with a 'low catch road' or 'high catch road' with regards to estuarine fisheries management. The high catch road scenario is characterised by the following six main attributes:

- Fisheries regulations rigorously enforced by dedicated staff, especially the removal of all illegal gill nets from our estuaries.
- Environmental legislation fully implemented by the relevant authorities.
- Implementation of the Environmental Water Reserve for estuaries by the Department of Water and Sanitation (DWS).
- Creation of a network of EPAs for fishes, especially for currently overexploited species.
- EMPs that include no-take zones are prioritised and implemented for all major estuaries.
- Improved angler awareness and compliance with regulations, including greater adoption of catch and release fishing within all recreational sectors.

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The low catch road below has a similar set of six bullets that need to be avoided at all costs if we want a sustainable future for our estuarine and coastal fisheries:

- Lack of fisheries regulations enforcement and increase in gill net poaching in estuaries.
- Poor implementation of environmental legislation by provincial and national authorities.
- Lack of implementation of the Environmental Water Reserve for estuaries.
- Ineffective protected areas that allow fishing and an absence of new EPAs to support the recovery of overexploited fish species.
- The rollout of EMPs is slow and ineffective in terms of implementation.
- Anglers remain poorly informed and mainly non-compliant in terms of fishery regulations, with catch and release fishing confined to an absolute minority of recreational anglers.

In conclusion, with the scientific evidence before us, can we afford not to take the high catch road?

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The St Lucia Estuary in the foreground and uMfolozi River in the background – both key components in the recovery of fish stocks for the entire lake system.

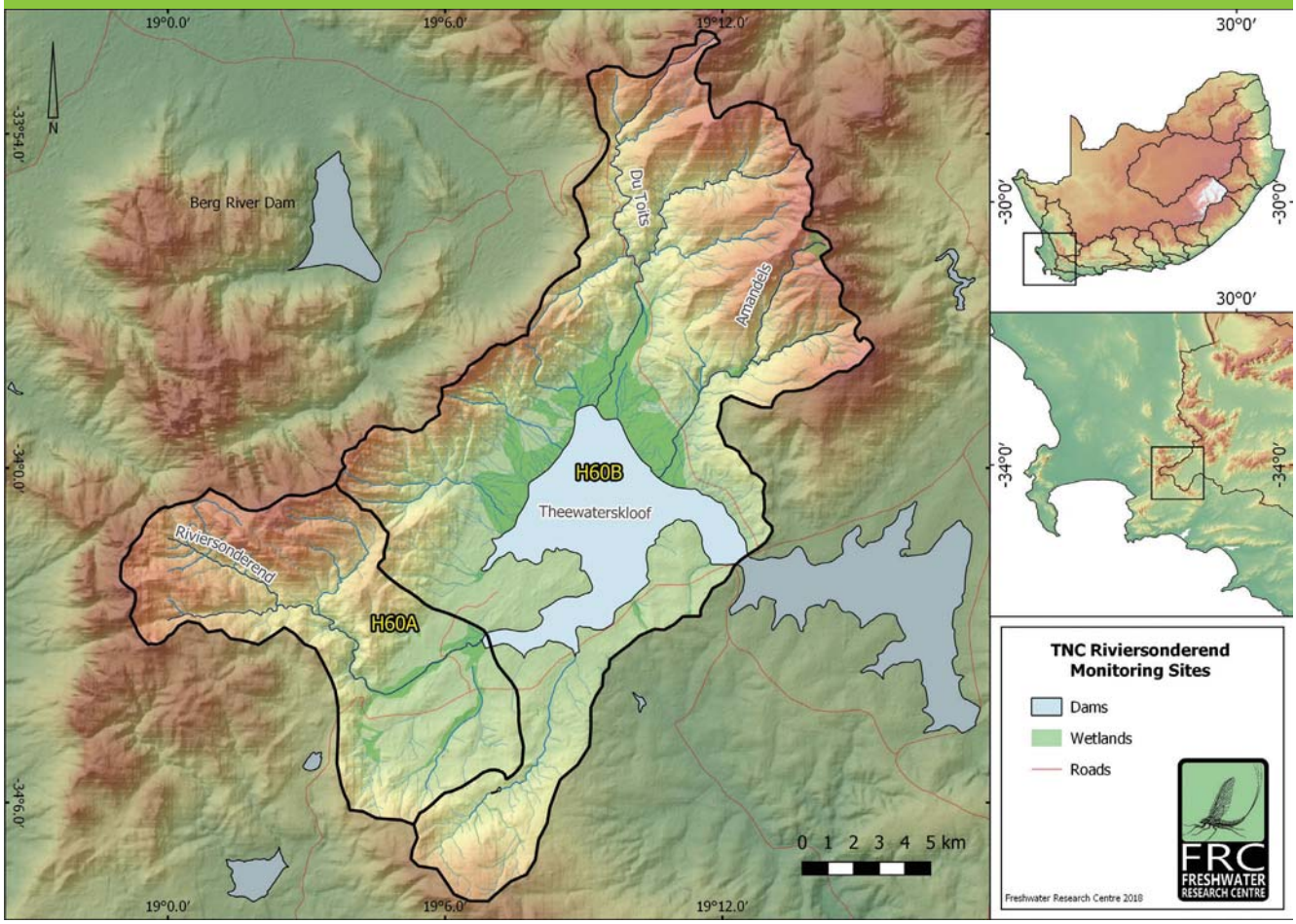
©Tor Naesje

The future of their estuaries is in our hands.

WATER AND THE ENVIRONMENT

Cape's endemic fish swimming for survival

A recent assessment of freshwater biodiversity in the Western Cape's Riviersonderend catchment provides new insights into the state of endemic freshwater fish species in the area. Jorisna Bonthuys reports on some of the findings.



The study area.

The endangered giant redfin (***Pseudobarbus skeltoni***) is doing better than expected in the Riviersonderend catchment, and palmiet seems to be linked to the health of endemic fish populations in the area.

Scientists have also documented an unexpected recovery of native fish populations in the lower Du Toits River, possibly due to the disappearance of alien invasive fish during the recent multi-year drought in the region. The lower catchment was also recently cleared of invasive alien plants.

These and other surprising results became known during a recent study of the upper Riviersonderend, Amandels and Du Toits rivers in the Western Cape's Riviersonderend catchment area.

The catchment supplies water to the Theewaterskloof Dam, the largest reservoir in the Western Cape Water Supply System (contributing 53% of the City of Cape Town's supply). This catchment is also in the heart of the Boland strategic water source area. These mountain catchments, primarily situated in

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the Cape Fold Mountains, operate as the 'water pumps' of the province. From here, water gets distributed across the landscape via rivers, dams and pipelines into our taps.

This catchment is situated in the southwest fynbos bioregion, which supports the highest level of endemism of wetland plant species in the whole of South Africa.

But it is not only unique fauna that matters in the region – the region's endemic fish populations are important too. This is the view of Kate Snaddon and Dr Jeremy Shelton from the Freshwater Research Centre (FRC) who participated in research in the area. The study, funded by The Nature Conservancy, is part of ongoing work to prioritise wetland restoration and other efforts to support water security in the Greater Cape Town area.

The Freshwater Research Centre's team of researchers compiled a document titled ***A Baseline Assessment for Freshwater Biodiversity Conservation in the Riviersonderend Catchment, South Africa: Threats and Interventions Report.***

The research aims to develop an overarching catchment 'picture' of water use and biodiversity pressure points in the area, Snaddon explains. Twenty-two baseline river monitoring sites were selected as part of the study. These were surveyed in December 2018 and March 2019. Data on the fish species were collected using a combination of sampling methods, namely snorkel surveys, fyke netting and electro-fishing.

A delicate balance

The Riviersonderend catchment has been identified as a freshwater ecosystem priority area due to the rivers' good condition and the presence of endemic freshwater species.

The water quality in the catchment's rivers is generally good, particularly in the upper reaches of all three rivers. However, as these rivers leave their pristine headwater catchment areas, they are exposed to human activity (primarily due to agricultural activities), and the water quality deteriorates. "This situation needs to be monitored to ensure that the quality of water entering Theewaterskloof Dam is as high as possible," Snaddon says. "Water quality in these rivers also affects the sustainability of freshwater biodiversity and the livelihoods of communities within the catchments."

The study area is considered a hotspot for freshwater fish endemism and conservation in the region. The catchment provides sanctuary for the endangered giant redfin, among others. This Breede River-endemic species is known from just three tributaries, Dr Shelton points out.

The study provides the first data on population extent and structure of the endangered giant redfins in the upper Riviersonderend. The species was found to inhabit 4.64 km of the upper Riviersonderend River, from a few hundred metres downstream of the CapeNature reserve boundary up into the remote and rugged Sonderend Mountains.

The researchers documented a healthy population of giant redfins in the upper Riviersonderend River, Dr Shelton indicates. Yet, despite its relatively large distribution in the study area, the giant redfin's survival is still threatened, including by pressures

Jeremy Shelton

The endangered Breede River redfin. This iconic freshwater endemic species thrives in rivers where habitat conditions are favourable and human-linked impacts minimal.

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Jeremy Shelton

The Galaxias sp. zebratus rectognathus, known only from the Amandel and Du Toit rivers in the upper Riviersonderend catchment in the Western Cape.

on its habitat. The reach downstream of the gauging weir, which appears to be an important source habitat for these endemic fish, is under pressure from invasive alien plants, for instance, which could reduce streamflow and habitat complexity.

Dealing with invasive alien plants in the area could be vital for the well-being of the giant redfins and the other endemic species inhabiting the upper Riviersonderend River, according to the researchers.

Why palmiet matters for fish

A total of 40 wetlands were mapped in the catchments studied, covering an area of 2 266 hectares. A large proportion of these wetlands are made up of palmiet beds. This unique wetland plant has been described as an 'ecosystem engineer' due to its ability to slow down water flow and trap sediment. But in addition to its important ecosystem-level role of trapping sediment and slowing down water flows, palmiet could also be important as habitat for native fish and as a dispersal barrier to non-native fish present in the dam downstream.

In both the upper Riviersonderend and Du Toits rivers, thick palmiet beds appear to play a role in restricting non-native fish distributions. They may prevent the alien fish from dispersing from the dam upstream into important native fish habitats, Dr Shelton explains. Further research is required to test this theory.

Native fish like the ***Galaxias spp.*** may use the palmiet to shelter from predation by larger fish species, and might also feed on invertebrates associated with palmiet. Similarly, thick palmiet beds may be preventing re-invasions of non-native fish species in the Sonderend River.

It is likely that palmiet, which dominates the middle to lower sections of both the upper Sonderend and the Du Toits Rivers, also plays an important role in both the hydrology and geomorphology of these ecosystems. The palmiet in this catchment is, however, under threat from a range of human impacts, including land-use practices and groundwater extraction. This could impact negatively on biodiversity and ecosystem function in the catchment, the researchers indicate.

Native fish recolonise a river

Historic data indicate that, while known to be abundant upstream of the old government weir on the Du Toits River, native fish have been scarce or absent downstream of the gauging weir in recent decades, probably due to predation by non-native predatory fish like black bass.

"Snorkel-based fish abundance estimates in the Du Toits River, however, shows native fish are now quite abundant downstream of the weir, indicating recolonisation and recovery of the native species in this section, perhaps in response to the absence of non-native fish," Dr Shelton says.

Possible reasons for the disappearance of non-native black bass (***Micropterus spp.***) from the lower Du Toits River include impacts of drought and predation by sharptooth catfish, he says. More research is, however, needed to confirm these suspicions. The researchers point out that the (re)introduction of the endangered Berg-Breede River whitefish (***Pseudobarbus capensis)***, which likely occurred in this section of river before bass invaded it, should also be considered.

More about the upper Riviersonderend catchment

- The catchment rises on the Groot Drakenstein Mountains and flows eastwards through the Riviersonderend Gorge within the Hottentots Holland Nature Reserve. As the river leaves the reserve, it enters a 222-hectare palmiet valley-bottom wetland.
- Most of this wetland has been classified as an aquatic critical biodiversity area in the Western Cape Spatial Biodiversity Plan for the Theewaterskloof Municipality.
- This catchment has been identified as a freshwater ecosystem priority catchment due to the good condition of the river and the presence of endemic and threatened freshwater species.
- The upper reaches of the Riviersonderend catchment provide sanctuary to the endangered giant redfin (*Pseudobarbus skeltoni*) which is endemic to the Breede River and known from just three tributaries.
- The river is also home to the Breede River redfin (*Pseudobarbus* sp. 'burchelli Breede'), the Riviersonderend catchment endemic Cape kurper (*Sandelia capensis* sp. 'Riviersonderend') and three genetically distinct lineages of *Cape galaxias* and *Galaxias zebratus* (one of which is endemic to the Riviersonderend catchment).

The heat is on

The severe multi-year drought in the Western Cape (2015-2017) recently provided a unique window into what the world could look like in the Western Cape over the next few decades in the context of climate change. "The drought provided us with a glimpse of conditions expected to become a lot more common in the decades ahead," Dr Shelton says.

New research by the FRC in partnership with the South African Institute for Aquatic Biodiversity (SAIAB) shows just how sensitive many of these threatened endemic fish species are to changes in water depth, streamflow and rising temperatures. "Drier conditions and a lack of water security also have an impact on the Cape's endemic fishes," he explains. "The Western Cape is especially vulnerable to reduced rainfall and rising temperatures that global change models predict."

The Breede River redfin seems particularly vulnerable in a warmer world. "Already, its current distribution patterns are fragmented," Dr Shelton indicates. The research shows that this species is likely to become extinct under fairly conservative climate change scenarios.

"The extinction threat is quite high for some of these fishes and we must conserve them as best as we can," Snaddon adds. "Water security not only matters to people, but also to biodiversity in the area – a delicate balancing act that now requires urgent attention."

River health, water flow remains key

The main purpose of the project was to establish baseline patterns in biota, aquatic habitat condition (including flow) and river health, Dr Shelton highlights. Future work in the area should build on this foundation by continuing to track changes in these freshwater ecosystems, particularly in response to key threats like invasive species, climate change and over-abstraction.

"In the face of uncertainty, it is clear that the need to balance human water use and environmental water requirements is about to become a whole lot more complex," adds Dr Bruce Paxton, a flow specialist at the FRC. "Surveys show habitat is being lost, and our research shows how sensitive the species are to changes in the environment, and our distribution models show the risk of species extinction during this century," Dr Paxton says.

Good water quality is particularly important in the Riviersonderend catchment due to the livelihoods that depend on agriculture and the fact that the rivers in this catchment feed into the Theewaterskloof Dam.

One of the most significant findings of this study was that ***Galaxias rectognathus*** appears to use fast flowing riffles and runs which is unusual for a Galaxias, which are more commonly associated with slow-flowing river reaches and marginal vegetation. "It demonstrates how little we know about these species and how much we still have to learn," Dr Paxton summarises. "It is especially important considering that shallow fast-flowing habitat is relatively scarce living-space in a river and usually the most sensitive to flow reductions and water abstraction."

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Jeremy Shelton

Dr Bruce Paxton with endemic giant redfin.

Given the highly-threatened status of the majority of indigenous fish in the province, there is a need to prevent new invasions while managing the impacts of invasions in priority areas. Once established, the management of alien invasive fish is complex, and few methods exist that will result in complete eradication.

"It remains critical to investigate and model the effects of water quality, water flow and the effects of climate change on our aquatic ecosystems to inform water resource management and policy," Snaddon concludes.

Visit http://frcsa.org.za for information

Did you know?

- The freshwater fish fauna of the Cape fynbos region is characterised by low species diversity (23 species) and high endemism (20 species), with several species restricted to very small geographic ranges
- Fourteen of the 20 fishes endemic to the region are considered 'vulnerable', 'endangered' or 'critically endangered' by the International Union for Conservation of Nature (IUCN)
- Human-linked degradation of aquatic habitats, including the introduction of non-native freshwater fishes and water abstraction, has caused dramatic decreases in the distribution and abundance of many of these species over the last century
- Invasive alien species remain the biggest threat to many indigenous fish species in the province, but now climate change is also starting to take its toll
- Research using molecular techniques has revealed that the fynbos region's freshwater fish diversity has probably been severely underestimated. Species previously thought to be widespread are now being split into species complexes consisting of several genetically unique lineages. Many of these species might occur over very small distribution ranges, some limited to single catchments or streams.

Source: The Nature Conservancy and CapeNature

Jeremy Shelton

The Cape kurper population in the Riviersonderend catchment is genetically distinct from those elsewhere in the Breede River system. It is currently being reclassified as a separate species.

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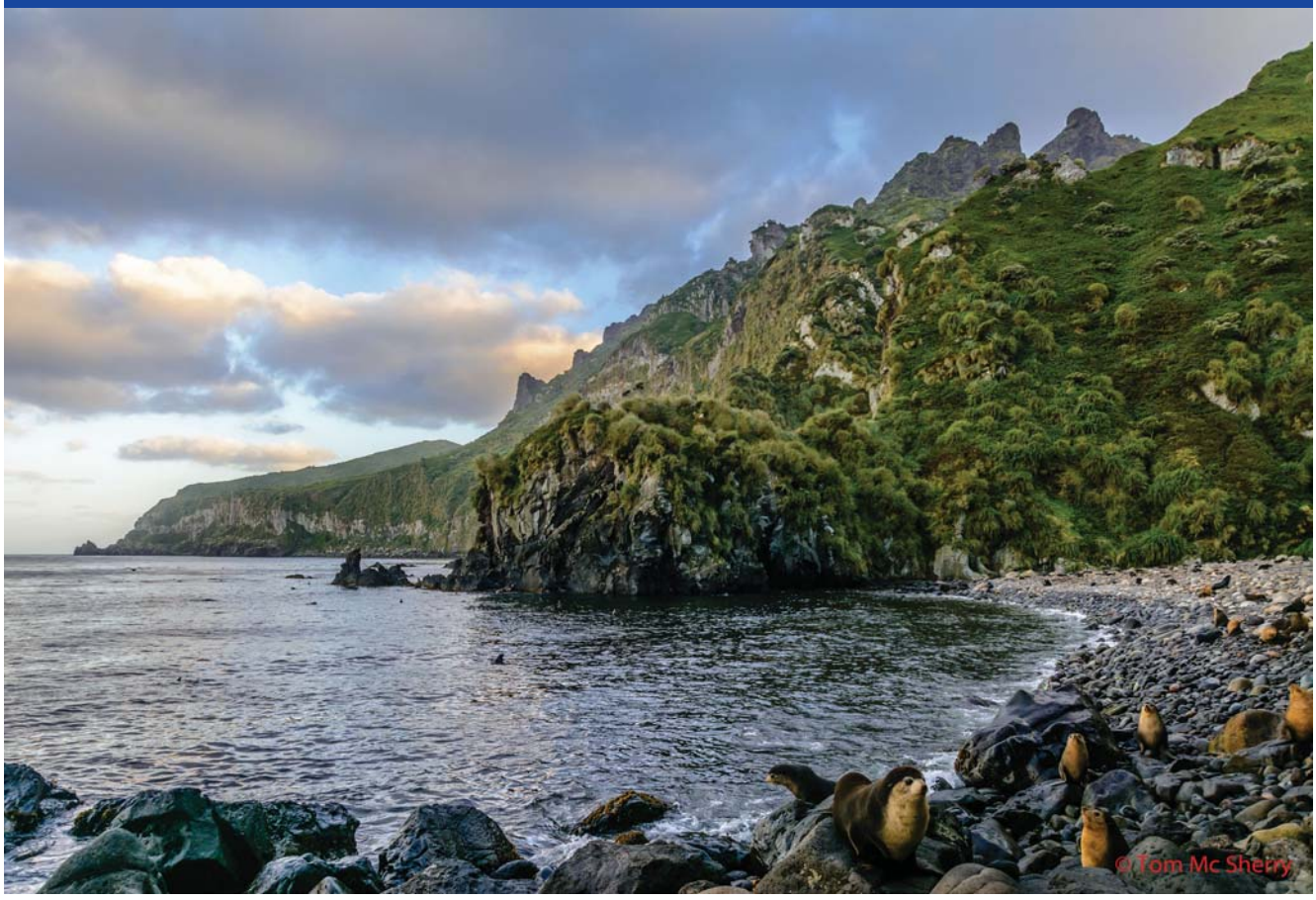
WEATHER FORECASTING

Gough: The remote island that all South Africans depend on

How South Atlantic island has become critical to weather forecasting in South Africa, and beyond. Article by Petro Kotzé.



Tom McSherry

Every October, a small crowd gathers at the East Pier Quay at Cape Town's Waterfront to welcome the SA Agulhas II back home again. As one of only five official gateway cities to the Subantarctic and Antarctic regions, the ship docks in Cape Town a number of times a year. Except for research missions, it ferries teams and equipment to and from the South African National Antarctic Programme (SANAP) stations.

Each May, the ship returns with staff from Marion Island, where South Africa constructed its first scientific base in the Subantarctic. In February, the ship returns from the Antarctic station. Though the entire region is one of extreme weather and daunting landscapes, the October voyage, however, marks the return from one of the most remote places on Earth with a constant human presence. It's called Gough Island. With it, the SA Agulhas II brings the handful of South Africans that just spent a year on a secluded volcanic outcrop, back home.

Gough is described as a lonely place. The total human population numbers five to eight people: three meteorologists, a doctor, a diesel mechanic and field assistants. Their mission? To collect integral data from a weather station on the island. Though most South Africans are unaware of the small team's presence on Gough, their persistent gathering of this data benefits us all, and reverberates far beyond the borders of the country.

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The Subantarctic

According to the Scientific Committee on Antarctic Research (SCAR), the Subantarctic area includes islands from c. 40°S (e.g. Gough Island) to those south of the Antarctic Polar Front (e.g. South Georgia, Heard Island). It includes large portions of the Southern ocean and some of the only land between 35°S and 60°S. For the purposes of SCAR, in 1958 "Antarctica" was defined as being bounded by the Antarctic convergence, as well as the Subantarctic islands on which International Geophysical Year observations were being made (which included Gough Island). The Australian Antarctic Division defines the Antarctic convergence as the region of the Southern Ocean encircling Antarctica, roughly around latitude 55 degrees South (but deviating from this in places) where the cold waters of the Antarctic circumpolar current meet and mingle with warmer waters to the north.

Where is Gough Island?

Gough lies about 2 600 km from Cape Town, and just over 3 200 km from the point closest to us in South America. The island is part of the Tristan da Cunha group of islands, which lies about 400 km North West from Gough. The islands are, with Saint Helena, British territory. Since the 1950s, South Africa has been leasing a patch of land to run a weather station, which is now technically a district of Cape Town. The weather station is managed by the South African Weather Service (SAWS) and the members of the teams stationed there are part of SANAP. As with all of the country's Antarctic stations, it is administered by the Department of Environmental, Forestry and Fisheries, Directorate: Southern Ocean and Antarctic Support.

Gough Island is 91 km^2 in size, with peaks up to 900 m above sea level. There are also small satellite islands and rocks; places like Saddle Island, Round Island, Cone Island, Lot's Wife, Church Rock, Penguin Island, and The Admirals. Conditions are harsh. The island clings onto the edge of the "roaring forties" in reference to its location between 40° and 50° south in the South Atlantic, and the frequent gale-force winds. Summers are cool, rain falls often and sunshine is scarce.

This then, is where the South African team observes various climatic parameters and keeps an eye on the automatic weather station. Port Meteorological Officer for the SAWS (Cape Town Weather office), Mardené de Villiers, explains that they do this in 24 hours shifts, 365 days a year.

Gough Island and weather forecasts

The automatic weather station includes temperature and humidity sensors, a wind sensor and a pressure sensor, explains de Villiers. All other parameters are measured by the observer on duty, one of the three meteorologists based on Gough. They log parameters of temperature, humidity, pressure, wind speed and direction, horizontal visibility, cloud height and type, present and past weather, and rainfall.

Julius Kette

Approaching Gough Island on the research vessel.

Twice a day they also launch a weather balloon into the upper atmosphere. Attached is a radiosonde, a battery powered telemetry instrument to measure various atmospheric parameters and transmits them by radio to a ground receiver. De Villiers explains that the balloon's flight into the upper air provides a crucial vertical profile of the atmosphere. Here, the instruments collect real-time temperature, humidity, pressure and wind speed and direction.

Last, she says, they also monitor data from a mounted weather buoy on Tristan da Cunha, where valuable atmospheric pressure data is collected.

The weather station thus operates much in the same way as others across South Africa, which also commonly provides hourly climate observations and upper-air ascents (collecting data with weather balloons). Yet, the volcanic island's location makes the data from here particularly important.

Data from the west

The majority of the weather systems affecting South Africa originate to the west of the country, says SAWS Senior Forecaster, Kate Turner: "This is because the predominant wind flow that governs these weather systems is from west to east, which results in the weather systems affecting South Africa moving in the same direction." As a result, it is crucial to have data stream to the west of South Africa to understand and gather information of the approaching weather, she explains.

Looking to what lies to the west of country, the choices of locations for weather stations are severely limited. In fact, the whole region is described as "extremely data sparse for climate studies" and Gough is one of the few locations filling this gap.

Turner explains that the data from Gough is not only beneficial for information on approaching weather systems, but also for a better, 3D picture of the atmosphere at that specific time. This data gets fed into numerical models for an indication of the state of the atmosphere, she says. "The more data points we have from across the southern African domain, including land and ocean, to "colour in" and map the current state of the atmosphere, the better the model forecast will be." If you do not have good and

sufficient data to feed into the models, she says, you cannot expect good, high quality forecasts.

As such, the data from Gough is integral for weather forecasts across southern Africa, and for warnings of looming severe weather.

Turner further points out that the data gathered from Gough and other stations over the decades is "extremely important" not only for research purposes, but also to understand climate conditions and to map changes to the climate over time.

The impact of the data ripples across and beyond South Africa. First, it is used for direct day-to-day forecasting for the island itself and particular operations that require an indication of the weather, says de Villiers. Then, the data from Gough is vital to forecast weather across southern Africa. "The data is also sent to the Global Telecommunication System (GTS) where various international users access it to be incorporated into global weather models." Last, it is also used for various research projects.

Now reaching back over half a century, the data set from Gough has become indispensable to local and international climate studies, as it is for the everyday lives of countless South Africans. We access the fruits of their labour easily. We can see it every time we check the weather forecast online, open the newspaper or watch it over the news.

However, the effort to obtain the data is more obscure. Digging into the archives of the Antarctic Legacy of South Africa, our history in the region is marked by great scientific achievement, as well as tales of "mutiny, attempted murder, shipwreck, drownings and much more," as written by Lieut. Frank McCall, who led the first missions to build South Africa's weather stations in the region.

South Africa's rich history in the Antarctic and Subantarctic region

South African activities in the Antarctic already began in the previous century, when sealers launched their ships there from Cape Town. However, the national flag of the Union of South Africa was formally raised on Marion Island for the first time on 29 December 1947. The feat was part of operation ***Snoektown***, a naval operation during which the uninhabited, Subantarctic archipelago of the Prince Edward Islands was officially annexed by South Africa.

According to McCall, "The story begins in 1954 when Jannie Smuts, the Prime Minster of South Africa, sent a confidential message to certain scientific authorities warning that South Africa had better occupy the Prince Edward Islands before Russia did. This would be by means of a weather-research station." Volunteering for the job, McCall wrote of "a lonely, wild, volcanic island halfway to the Antarctica mainland," where they subsequently put a small group of weathermen in a tiny hut. "They were the only human inhabitants," he wrote. "This was Marion Island." At least one relief expedition per year to the weather station on Marion has been carried out ever since.

As was required by the Weather Service, the weather balloon is released on Gough Island twice a day (photo taken in1968).

Tom Mcsherry

A Tristan Albatros during mating season.

Motivation for the establishment of the next weather station, on Gough, was driven by the International Geophysical Year of 1957/58. The initiative entailed scientists from around the world taking part in a series of coordinated observations of various geophysical phenomena. Activities spanned the globe from the North to the South Poles, but special attention was given to the Antarctic (see sidebar on definition of the area), where research on ice depths yielded radically new estimates of the Earth's total ice content. The research also contributed to improved meteorological prediction, advances in the theoretical analysis of glaciers, and better understanding of seismological phenomena in the Southern Hemisphere.

"Data gathered from Gough and other stations is extremely important not only for research purposes, but also to understand climate conditions and to map changes to the climate over time."

In preparation, the weather station was established on Gough in 1956, to be operated by South Africa. McCall writes of a mission to "work out where to put a base on that uninhabited island which lies south of Tristan Da Cunha." Pending the building of the base, he writes, some weathermen were left there in a small hut. McCall writes that on his return six months later, the leader was "raving". "He had tried to exercise authoritarian rule over his group and they "sent him to Coventry" (refused to talk to him.)"

A weather station was consequently built at a place called 'The Glen', and later moved to the South Western lowlands of the islands (in 1963) for more accurate weather observations.

South Africa has paid expensively for its presence on Gough. According to a ***History of South African involvement in Antarctica and at the Prince Edward Islands*** by J Cooper and RK Headland, "Gough Island may be reckoned as a dangerous place: four team members have died there since 1956, three by exposure in the mountains and one by drowning while fishing."

SANAP's last scientific station was built on the Antarctica mainland in 1961. First called Norway station, it was later renamed South African National Antarctic Expedition (SANAE) and has been in continuous operation since. The current South African research base, SANAE IV is located at Vesleskarvet, Queen Maud Land.

Though it cannot be described as a hospitable environment to humans, Gough Island is special for various reasons beyond meteorology. It's a UNESCO Natural World Heritage Site, a Ramsar Wetland of International Importance and part of the Tristan da Cunha Nature Reserve. It's also been declared an Important Bird and Biodiversity Area, and is considered home to one of the most important seabird colonies in the world.

The other inhabitants of Gough

Gough Island is one of the only homes to the critically endangered Tristan Albatross. January dated newsletters written

by those stationed there, tell of the interior of the island dotted with white birds nested on mounds that hold their enormous white eggs. While the Tristan Albatross is perhaps its most famous avian inhabitant, the island is also home to almost the entire global breeding populations of the endangered Atlantic Petrel and MacGillivray's Prion.

These are some of the 22 breeding seabird species found on Gough Island. It's also home to 35% of the population of the endangered Sooty Albatross, and about 20% of the endangered Atlantic Yellow-nosed Albatross**.** The Gough Finch and Gough Moorhen are endemic to the island.

Unfortunately, the birds are paying a price for human habitation of the island. Docking at Gough in the 19th century, house mice reportedly arrived with those sealers. They are famously big, having grown substantial larger than house mice elsewhere due to the favourable conditions the island offers. There are no natural predators or competition for the food that's available in ample supply. Especially in winter, this takes the form of vulnerable Tristan Albatross and Atlantic Petrel chicks. Bird numbers have dropped dramatically as a result. In partnership with the Royal Society for the Protection of Birds, the Department of Environmental, Forestry and Fisheries is launching a mice eradication programme in 2020.

The island is not completely out of bounds to South Africans. As per agreement, the annual Gough Island relief voyage with the SA Agulhas II also takes paid passengers to Tristan die Cunha on its outward and return voyage, stopping at Gough along the way. For most of us however, the near imperceptible connection to Gough remains to be via our everyday weather forecasts.

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- *Thanks to the Antarctic Legacy of South Africa (ALSA) for the photographs used in this article.*

Inspecting the Stevenson screen in 1978.

AGRICULTURE AND WATER

Agriculture's water challenges – Digging for solutions

Taking into account future uncertainties, how can South Africa ensure that it uses its water resources sustainably whilst promoting economic development and food security? Jorisna Bonthuys reports on the proceedings of a recent water symposium hosted by Agri SA where this topic featured strongly.

The agricultural sector finds itself in "a serious predicament", according to University of Witwatersrand (Wits) Prof Mike Muller. "Agriculture needs to manage uncertain climates – both in terms of weather and politics," he explained. Prof Muller, adjunct professor at the School of Governance, highlighted the need for good water management at a recent Agri SA symposium in Somerset West.

As a former director-general of the Department of Water Affairs and Forestry (now Water and Sanitation), Prof Muller spoke of the need for South Africa to assume a "capable and developmental state" when it comes to managing its water resources. Prof Muller and other participants urged the Department of Water and Sanitation to implement the National Water Act (Act 36 of 1998), something successive administrations have failed to do in the past.

The availability and quality of water resources for agriculture remain under threat, according to Janse Rabie, Agri SA's policy head for natural resources. This calls for immediate attention, given the undisputed importance of the agricultural sector to South Africa's economy.

In 2017, for instance, Western Cape agriculture generated R45 billion for the economy. Agriculture sustains a R530 billion economy that employs 2,4 million of the province's 6,4 million

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citizens. Moreover, 45% of South Africa's agricultural exports come from the Western Cape. According to provincial MEC, Dr Ivan Meyer, agriculture also employs 16% of the labour force in the province, of which 231 000 people are agricultural workers and 250 000 work in agricultural processing.

A climate of change

Planning for a sustainable agricultural future remains key, given current and future realities. With the added pressures of climate change, population growth, the pollution-induced decline in water quality, failing municipal infrastructure and service delivery issues, the need for improved management of water resources is more critical than ever before.

Climate change prediction models suggest that average temperatures will rise and rainfall events will become more infrequent but also more intense, thereby increasing the unpredictability of (water availability for) agricultural production. The risk of more frequent extreme events, including floods and droughts, is also on the rise.

Many of South Africa's major metropolitan municipalities would be at risk if there were to be a serious multi-year drought. Gauteng has already been warned of a looming 'Day Zero' scenario in which the taps could run dry.

As the country's water resources become more constrained, the amount of water allocated to irrigation (~60% of total national water use) will come under increasing pressure, Prof Andries Jordaan indicated. Prof Jordaan, a research fellow at the University of the Free State, recently led a comprehensive agricultural water scenario-building process funded by the Water Research Commission.

Water management authorities need to manage water risks for the benefit of people, the environment and the economy. **"**Rising water demands, the need for water use efficiency, agricultural intensification and farming business all need attention," Prof Muller said. The challenges of agriculture increasingly have less to do with land, people and weather than with money, markets and management."

"Rising water demands, the need for water use efficiency, agricultural intensification and farming business all need attention. The challenges of agriculture increasingly have less to do with land, people and weather than with money, markets and management."

Although agriculture is the sector that uses the most water, it is important to highlight that it gets the "hyena's share" of the country's water resources, Prof Muller said. "This is because agriculture gets what is left over after industries, cities, Eskom and the environment have received their allocation.

"Remember, the issuing of (a water) license is no guarantee of supply. The sector, therefore, has to create more value from the same amount of water. Certain agricultural industries also need to ensure they have a social license to operate by making a positive societal contribution.

"We also need to cooperate more with our regional neighbours to ensure food security. Why is South Africa importing water-intensive crops into a water-scarce country? We need to consider what our neighbours can do better than we can."

Pollution remains a serious problem, causing water quality and quantity problems in various areas. Many water courses, including major rivers are polluted by poorly managed wastewater plants and unlicensed mining operations, Prof Muller indicated. There is also growing concern about the impact of water quality on markets, livelihoods and human health, especially along the Gariep and Vaal rivers.

A glimpse of what's to come

South Africa's agricultural system does not function in isolation. It interacts with developments and trends in the global, national and local economy, society and politics. Also, the food systems of the country – from the trade in raw materials to the final products – are intertwined in many ways.

Various drivers and associated trends are bound to impact on agriculture in the country, Prof Jordaan highlighted. "South Africa's water-related agricultural future can unfold in many ways," Prof Jordaan pointed out. "What we do know is that poor water management will harm the most vulnerable (in society)."

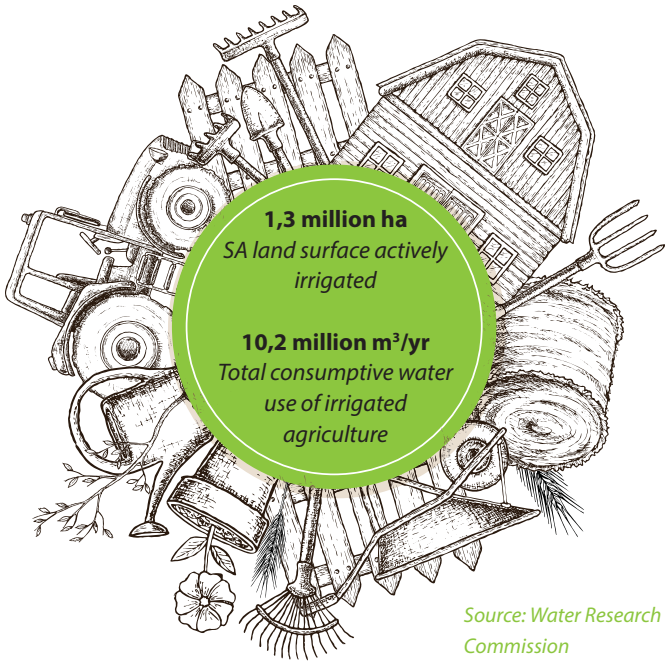
The agricultural water scenario-building process led by Prof Jordaan identified 65 drivers that will determine the future of water management. These drivers have been grouped in 10 clusters, he explained. The importance of drivers and the related clusters was determined through participatory research and data capturing, system dynamics and game-theoretic mathematical programming.

Four potential water management scenarios were developed. These include a "Traditional scenario", "Best-case scenario", "Z scenario" and "Frustration scenario".

In the "Best-case scenario", decentralised water management is embraced by water management agencies. This scenario requires strong governance, leadership and both public and private involvement. There is strong enforcement of water user guidelines, and water management authorities are efficient. There is also good collaboration between the private sector and the state where water is concerned. This enables the country to participate in and benefit from innovation in the Fourth Industrial Revolution.

In the "Z scenario", really a worst-case scenario, South Africa experiences water shortages, hyperinflation and disinvestment in agriculture. This scenario, in which there is no safety and security in rural areas, leads to food insecurity, land grabs, and a poor, small-scale agricultural sector. Commercial farmers relocate to other countries and food-importing increases significantly. At the same time, water infrastructure becomes dilapidated. The "Day Zero" threat becomes a reality for urban areas and agriculture during dry periods.

The "Traditional scenario" entails centralised water management and policies, low productivity and innovation in agriculture as well as increased competition between water users. Lastly, in the "Frustration scenario", the gap between the haves and the



Source: Water Research Commission

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have-nots increases. Poor enforcement of policies and laws, conflict about water use and unequal access to water could also become more pronounced.

At this stage, Rabie said, South Africa is showing signs of heading in the direction of the "Frustration scenario". This underlines the urgent need to tackle current water challenges.

Future-proofing agriculture

Agri SA identified several issues that need to be addressed if water risks in the country are to be reduced. Progress in efforts to tackle these issues will now be systematically tracked during regular engagements with the government, Rabie stated.

"One of the most urgent matters is to set up all nine catchment management agencies (CMAs) spelled out in the legislation (the National Water Act)," Rabie said. This was supposed to have been done in 1998, but only two of the nine have been established to date. CMAs allow for the decentralisation of water management through means of regional structures. This can help ensure proper water governance and integrated planning at a local level, Rabie indicated.

Anil Singh, Deputy Director-General in the Department of Water and Sanitation, conceded at the symposium that the department had failed to set up these agencies. He assured the audience that work is underway to get these structures up and running as soon as possible.

Another critical issue is how municipalities deal with water quality and pollution, which is endemic in our country. It is a huge concern for the government, Rabie indicated.

The issue of verification and the validation process of agricultural water use also needs attention, Rabie pointed out. "Without this information, evidence-based decision making to support a Water Sector Transformation Charter becomes impossible," he said. "To make water management institutions work, you must understand your resource, who is using it and how it is being used."

"Water allocation reform also needs to support land reform efforts and water pollution that has become a national epidemic," Rabie indicated.

Singh indicated that the department is battling to finalise the water allocation reform policy, which the agricultural sector has been pushing to have completed.

He also identified declining water quality as another major challenge for agriculture and pointed to the local government's failure to deal with this.

Another key challenge to be tackled is keeping water affordable. In this regard, Agri SA is encouraged by the department's "willingness to listen and engage with the sector", Rabie said. This willingness was particularly evident during the latest raw water tariff discussion.

Agri SA requested a water resource management charge increase of no more than 6.5% for the irrigation sector in 2020/21. The proposed raw water use charge was accepted by the Department of Water and Sanitation in the case of all areas except the proposed Orange River catchment management area where an increase of 15.66% is to be enforced in accordance with the national water pricing strategy.

Agri SA's proposal that water resource infrastructure charges be capped at 16.5% for the irrigation sector was also accepted. "This constitutes a substantial achievement, considering the department initially proposed increases of up to 50% for numerous areas," Rabie indicated.

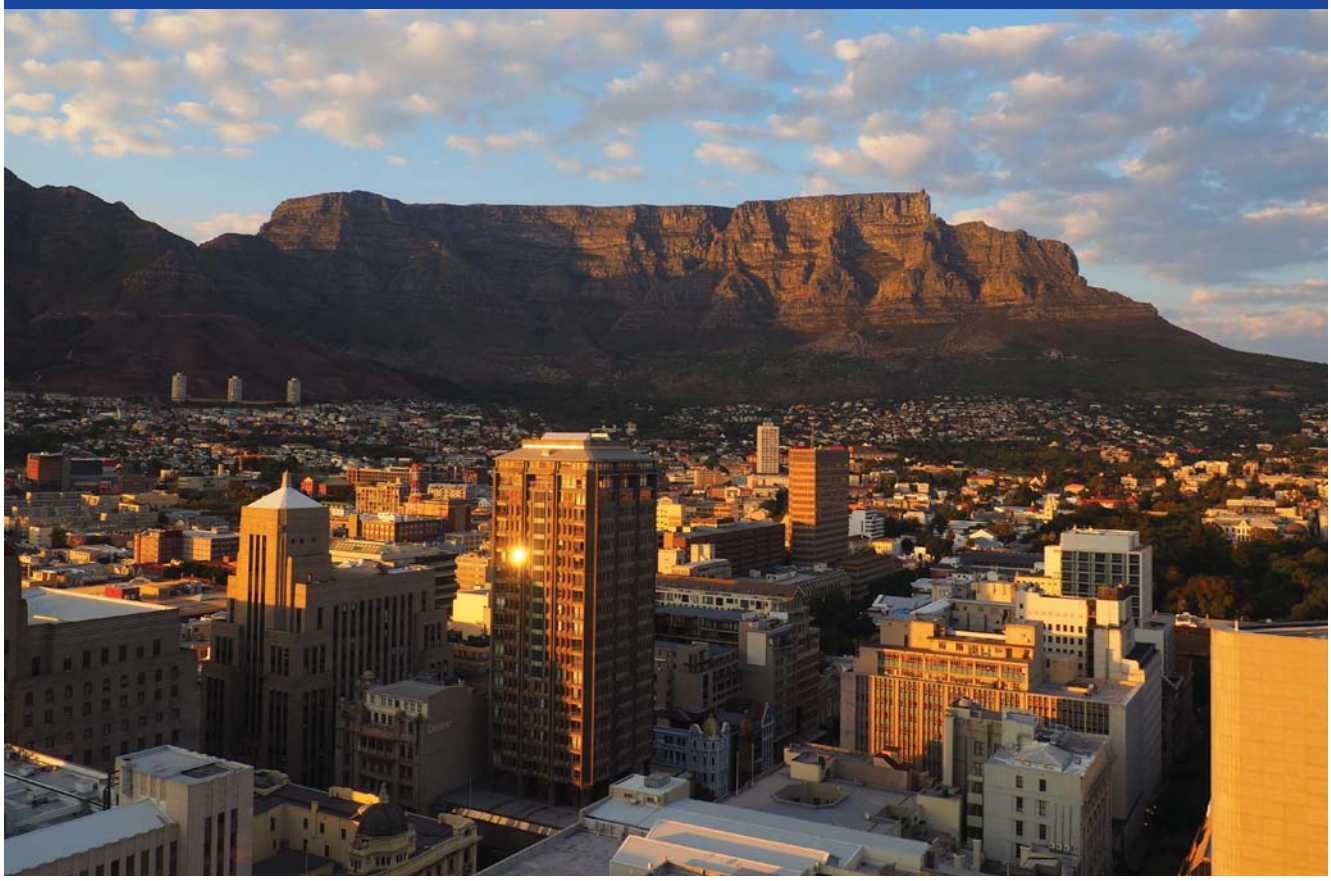
The need to improve the consistency and continuity of leadership among the country's water management authorities has also been identified. Agri SA would like to see the government issue the 'Green Drop' and 'Blue Drop' reports regularly. The first report indicates if municipalities comply with good wastewater discharge standards, while the second provides information on the quality of our drinking water. The department is obligated to release these reports annually, which give a clear picture of the quality of South Africa's water resources. The last full Green Drop report that drills down into the waste treatment plants managed by municipalities dates back to 2011.

"These and other challenges must now be tackled urgently and collectively," Rabie implored. "A good starting point will be to implement the National Water Act properly. "The key to unlocking change in water management is to build an inclusive culture of collaboration between the private sector and government," Rabie concluded.

RESILIENT CITIES

Water funds: Innovative tools to promote water security

Efforts are underway to establish 'water funds' in South Africa to help unlock investment in ecological infrastructure restoration, reports Jorisna Bonthuys.



The link between water security and catchment health has been in the spotlight since the recent three-year drought threatened to shut down the City of Cape Town's water supply at the height of the crisis in January 2018.

During this drought, water users and management authorities alike were confronted with the uncomfortable reality that water is indeed a finite resource. Although enough rain came down just in time to help prevent the city from running out of water, Cape Town's water woes are far from over. Water demand is predicted to outstrip current supply in the region by 2021 due to population growth and changing rainfall patterns.

Cape Town is not the only urban hub dealing with water security issues. In recent years, other metropolitan municipalities such as Nelson Mandela Bay (Port Elizabeth) and smaller municipalities in the Western Cape and other parts of the country have been under significant stress concerning their water resources. Of the eight metros in South Africa, seven implemented water restrictions in the summer of 2016/17 due to low dam levels.

Evidence suggests that a significant part of the recent multi-year drought (2015-2017) may be attributed to climate change, and that more events of this nature can be expected. Severe events are also becoming the 'new normal' in southern Africa due to the

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current rate of climate change. Not only the likelihood, but also the severity of extreme climate events are expected to increase in the near future.

"The situation paves the way for critically rethinking our water supply-side solutions," according to Louise Stafford from the global non-profit organisation The Nature Conservancy. "It is time to employ nature-based solutions alongside traditional engineered options to ensure water security in the region," Stafford says. "This requires catchment restoration efforts and investment in green infrastructure at scale – largely outside of municipal boundaries."

Stafford spearheads the development of The Nature Conservancy's water funds across the country. These funds are funding and governance mechanisms that enable water collective action between the public and private sector and water users to employ nature-based solutions such as catchment restoration at a fraction of the cost of engineered infrastructure. Downstream users, such as businesses and local governments, contribute to upstream conservation initiatives aimed at improving water quality and quantity for the region.

The case for nature-based solutions

Stafford and a team of researchers recently developed a business case for establishing the Greater Cape Town Water Fund. The fund supports targeted nature-based solutions, including catchment restoration. This innovative tool for securing water is the first of its kind in South Africa and the second of its kind in Africa. "The water fund is a public-private-partnership bringing different stakeholders and players together to invest in nature-based solutions for water security," Stafford explains.

Thus far, R39 million has been contributed to this fund by its partners and donors. The Nature Conservancy is currently the secretariat of the fund. Together with its partners, this non-profit organisation aims to restore key priority areas to replenish surface water and aquifers that supply water to the City of Cape Town and surrounds.

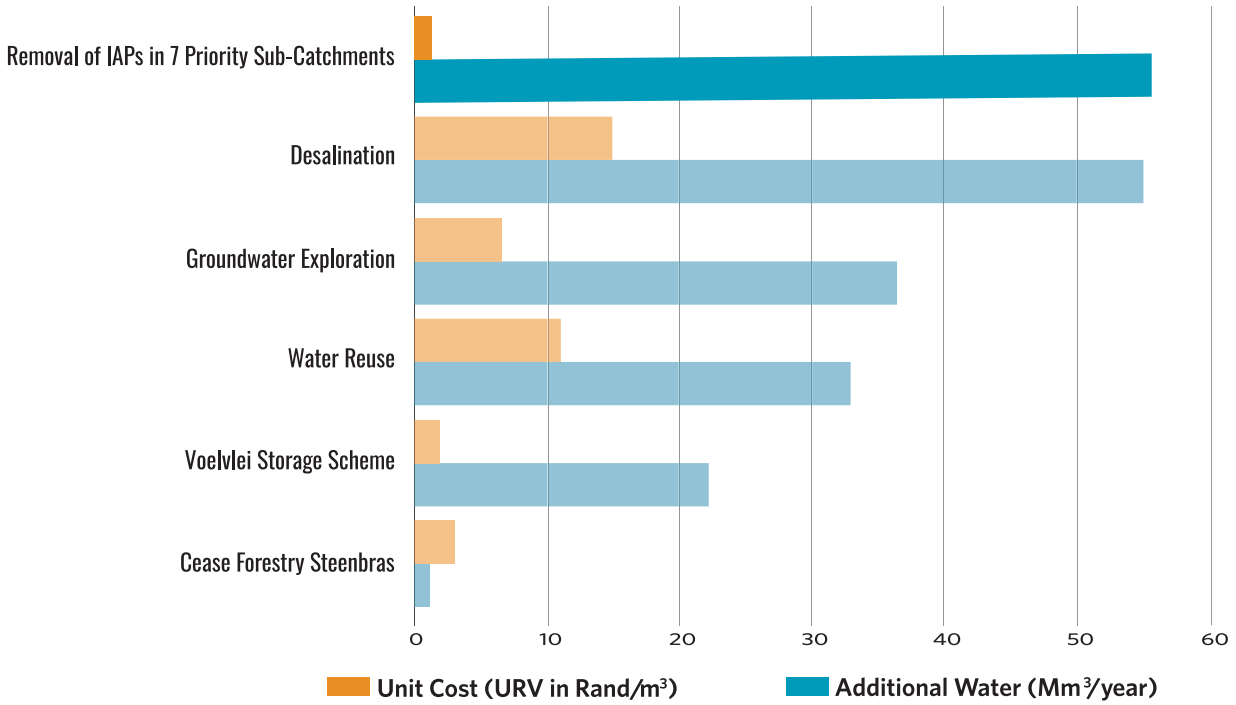
The water fund model could provide a successful tool for intervention in key areas across the country, according to the researchers. "The fund is a catalyst and tries to fill gaps in restoration efforts rather than duplicating existing efforts," Stafford says.

Efforts are also underway to establish water funds in the Palmiet-Bot region of Grabouw and Elgin, the Overberg, eThekwini (Durban), the Garden Route, Port Elizabeth (Algoa), and Polokwane.

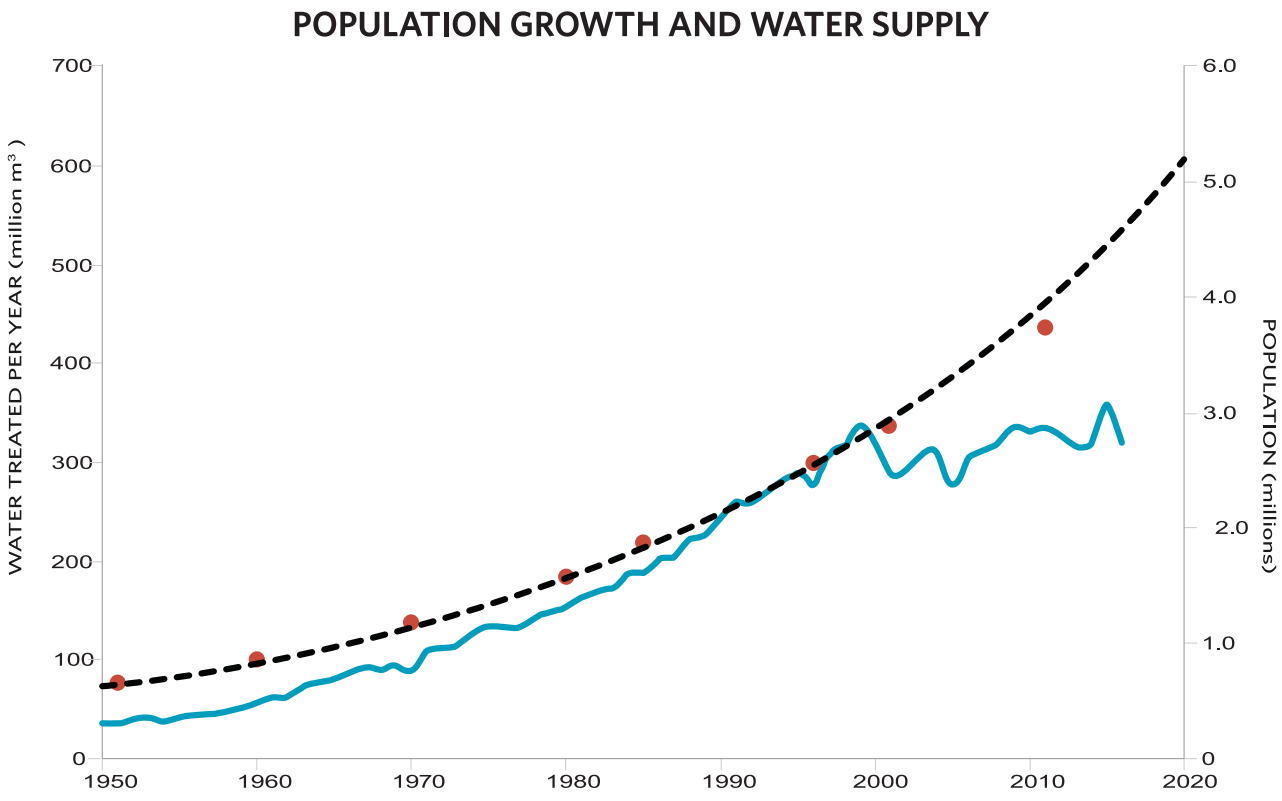
These and other water funds build upon The Nature Conservancy's experience with establishing the Upper-Tana Nairobi Water Fund in Kenya, and in North and South America, where over 30 water funds are operating and several more being developed. These include new water funds in Kenya, Sierra-Leone and Gabon in Africa.

"Water funds are founded on the principle that it is cheaper to prevent water problems at the source than it is to address them further downstream," Stafford explains. "These funds are not taking up the mandate of governments or duplicating or competing with existing initiatives. Water funds are catalysts for bringing about systemic change, supporting and building capacity for securing water at scale."

CATCHMENT RESTORATION INCREASES WATER SUPPLY AT THE LOWEST UNIT COST



Source: The Nature Conservancy



Source: The Nature Conservancy

Cape Town's population growth is outstripping water supply.

So far, water funds have typically been established where there are market failures. This includes situations where the price of water does not reflect the true cost (including environmental costs) of delivering it to users.

The Greater Cape Town Water Fund already has a strong coalition of partners that form part of its steering committee. This list of partners includes the Department of Water and Sanitation, the Department of Environmental Affairs, provincial authorities, the South African National Biodiversity Institute, CapeNature, Nedbank, Coca-Cola Peninsula Beverages, Remgro, PepsiCo and WWF South Africa. To date, the fund has received financial support from PepsiCo, The Coca-Cola Foundation, Levi Strauss & Co, the Caterpillar Foundation, Proctor & Gamble, private individuals and foundations.

To support strategic investment in ecological infrastructure, the fund's steering committee has commissioned some studies, including research to prioritise wetlands for investment in water security through alien clearing efforts in priority dam catchments in the Western Cape.

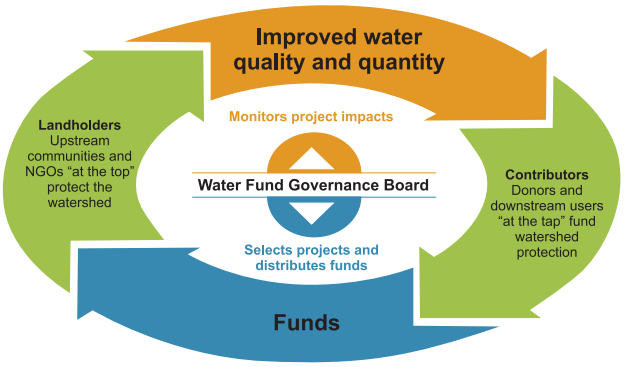
The fund aims to improve water security in the area that gets water from the Western Cape Water Supply System (WCWSS) by focusing on seven priority sub-catchments. The WCWSS is made up of 14 dams, and three aquifers connected by a network of approximately 11 600 km of pipelines, reservoirs, canals, and pump stations.

From source to tap

Stafford and the team of researchers considered the return on investment for ecological infrastructure restoration in the WCWSS. This area includes the catchments of the six major dams supplying water to the City of Cape Town – Steenbras Dams (Upper and Lower), Theewaterskloof Dam, Wemmershoek Dam and Berg River Dam.

The business case analysis modelled a 30-year period, discounting both costs and water gains. The spotlight fell on water quantity and the timing of flow or recharge, in particular.

"Nature-based solutions can work alongside and complement built or 'grey' infrastructure to help provide sustainable solutions for water demands".



According to The Nature Conservancy, a water fund is "a funding and governance mechanism that enables water users to invest collectively in catchment restoration alongside upstream communities.

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Invasive alien plants – including pine and black wattle – are water-thirsty and have a significant impact on water yield in the province. Estimates show that water resources in the Cape Floristic Region have already been reduced by 15% due to alien invasive plants. This could rise to 37% (from 6 765 to 4 271 million m^3/year) if invasions were allowed to reach their full extent.

There is no doubt that demand-side management is important for water security in the region. This approach is, however, not sufficient. "There is a need to augment the water supply," Staffords says. "This could be done with a combination of catchment management and engineered infrastructure such as raising existing dam walls to increase capacity and water reuse."

The true cost of 'new' water supplies

It is important to consider the real cost and benefits of plans to augment the city's supply of water over time. The researchers identified seven of the 25 sub-catchments in the WCWSS as priority areas for alien plant removal. These areas comprise a total of 54 300 hectares and are sub-catchments for the Theewaterskloof, Wemmershoek and Berg River dams.

Other than demand-side management, catchment restoration has the highest return on investment, according to their analysis. Investing R372 million now will generate expected annual water gains of 100 billion litres (100 Mm^3) within three decades at one-tenth of the cost of other options such as desalination and exploration of the Table Mountain Group Aquifer. This aquifer system has been identified as an important water source for the province. "Importantly, invasive alien plant removal would already yield up to an additional 55 billion litres annually within only six years," Stafford says.

If no action is taken, water loss could double in only two decades. Clearing invasives would also create approximately 350 jobs, according to the business case.

Over two-thirds of the catchments supplying the WCWSS are already affected by alien plant infestations, reducing the amount of water that reaches the rivers and dams that feed the region by 55 billion litres (55 Mm^3) per year. This equates to about two month's water supply for Cape Town. "Research shows the Greater Cape Town region loses 74% of its potable water in just 19% of its catchment," Stafford indicates. "By focusing on only 19% of the WCWSS and get that back in shape through ecological restoration, we gain 74% of the current water losses as a result of alien plant invasion."

Investing in nature-based solutions is a "no-brainer," Stafford argues. "In many cases, nature-based solutions can work alongside and complement built or 'grey' infrastructure to help provide sustainable solutions for water demands.

"Long-term water security in the Greater Cape Town region, as elsewhere, begins at the source."

Future-proofing water supplies

While the scope of the Greater Cape Town Water Fund will be mostly on alien invasive plant removal, efforts will also be made to invest in other ecological interventions. These include wetland and riparian restoration, clearing areas where forestry activities are coming to an end, and the restoration of the Atlantis Aquifer. This aquifer is situated on the West Coast north of Cape Town and contributes to water security in the area.

The good news is that degraded catchments providing the Cape's water can be restored. "Clearing of alien vegetation has already had a significant impact on the flow of the rivers, streams and wetlands," Stafford says. "But it is essential to maintain the cleared areas to avoid invasive plants from growing back. If areas are not maintained, the resources invested in clearing such areas are simply wasted."

Options such as desalination are very energy-intensive solutions and this must be taken into consideration when making decisions about augmenting the water supply. Current supply augmentation solutions for the City of Cape Town are estimated to cost R8 billion in capital costs alone, according to The Nature Conservancy's analysis.

"Catchment restoration is significantly more cost-effective than other water augmentation solutions, supplying water at one-tenth the unit cost of these alternative options," the report concludes.

- For more information, contact Stafford at 021 201 7391 or Louise.Stafford@TNC.org or visit nature.org/cape-town-water.

More about water source areas

- South Africa's water source areas produce disproportionately greater volumes of water in relation to their size. Only 8% of the country provides us with 50% of its surface run-off.
- South Africa has 22 strategic water source areas, situated in five provinces. From here, water gets distributed across the landscape via rivers, dams and pipelines into our taps.
- The Western Cape holds 57% of the strategic water resources in the country. These mountain catchments, primarily situated in the Cape Fold Mountains, operate as the 'water pumps' of the province.
- The City of Cape Town receives 98.8% of its water from the Boland Mountains and the Table Mountain water source areas. The Boland Mountain's water source area supports more than 4 million people.
- Only 42% of the source water areas providing water to the Western Cape Water Supply System are under formal protection. This system delivers water to Cape Town and surrounds.

Source: WWF South Africa, Centre for Environmental and CapeNature.

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SMALLHOLDER IRRIGATION

Smallholder irrigation schemes under the spotlight

A recently completed project funded by the Water Research Commission (WRC) investigated factors influencing the under-utilisation of smallholder irrigation schemes in Limpopo and opportunities for improvement. Sue Matthews reports on the lessons learnt.

For a time, the situation looked promising at Kolokotela irrigation scheme, located in Limpopo's Sekhukhune District. The government, via the provincial agriculture department, paid for a state-of-the-art floppy sprinkler system and pump station to be installed, and a strategic partner was brought in for an agreed three-year period to operate the scheme in conjunction with the 188 beneficiary farmers.

The partnership's first year generated a profit, but for the next two years the strategic partner reported losses. Since he didn't fully share all the information on financing, income and expenditure, the farmers didn't believe him, and conflict ensued. So the strategic partner left, sometime in 2010, and the scheme fell into disuse. Over the years, vandalism and theft took its toll, and today there are few signs that an irrigation scheme existed there. Even the poles supporting the overhead sprinkler system have been sawn off and stolen, leaving a field of stumps.

Sadly, this is by no means the only collapsed smallholder irrigation scheme, and many more are limping along, perhaps producing food and income at a subsistence level, but certainly not turning a profit. Success stories are few and far between, but those that do exist are just as useful as the failed schemes in identifying lessons to be learned.

The WRC has funded a number of studies over the years to investigate the reasons for poor performance of smallholder irrigation schemes and to propose remedial action. Recently, Jabulani Jiyane and Timothy Simalenga of Agri-Eng Consulting produced the report of their research project focusing on six schemes in Limpopo Province. The schemes were selected with the assistance of the Limpopo Department of Agriculture and Rural Development (LDARD), and included both failed and successful examples, as well as three types of ownership: communally initiated and owned, government-initiated

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and communally owned, or privately owned public-private partnerships.

During October 2018 the project team visited each scheme, where they conducted an interview with a panel of farmers, committee members, extension officers and relevant stakeholders. An assessment template had been developed to record information on aspects such as beneficiary socio-economics, crop and soil types, irrigation infrastructure and management, and markets and finance. After each interview, a transect walk of the scheme was done to assess pump stations, balancing dams, infield irrigation and power supply, as well as the general condition of soils and crops.

The success story in this case was the Mphaila irrigation scheme, trading as Chime Agricultural Cooperative, in the Vhembe District. The scheme is demarcated into blocks averaging a hectare each for the 62 individual household farmers, who make their own decisions on crop selection, irrigation scheduling and marketing. The cooperative's marketing team has established firm relationships with a number of sales outlets, however, and crop inputs are purchased in bulk, so the farmers benefit from discounts. There is an experienced agricultural extension officer living on site and providing ongoing advice and support, and formal training has been given in aspects such as agro-processing, soil and water conservation, nursery management and chemical safety. The farmers have organised themselves into study groups, and there is a concerted effort to involve youth to ensure a succession plan. At the time of the visit, the irrigation system was in the process of being changed from overhead sprinklers to drip irrigation.

Taking the successes and failures of all six smallholder irrigation schemes into account, the project team were able to identify the key factors contributing to their underutilisation.

Problems posed by cooperative farming

"The study showed that the cooperative concept in smallholder irrigation farming does not work," noted the project team. "The allocation of farms or plots to several people resulted in conflicts and infighting, causing either the collapse of the smallholder farming or reduced production levels. This finding is corroborated by several other studies carried out in South Africa, Africa and other places." The project team instead advocated the 'one block one household' approach, and pointed out that irrigation methods that do not allow for demarcation into individual blocks, such as the floppy irrigation system, are not suitable for smallholder irrigation schemes owned by several beneficiaries.

Lack of skills in irrigation scheduling

All the schemes were found to rely on "crude and inaccurate methods for determining when to irrigate and how much water to apply," noted the project team. This has direct implications for crop quality and yield. What's more, a few of the schemes were making use of furrow irrigation, resulting in water use inefficiencies and – in some cases – soil erosion.

Problems with the strategic partner approach

The strategic partnership model was introduced to capacitate and mentor farmers, but its effective implementation requires an agreement for each scheme specifying how both parties will participate and benefit. Typically, strategic partners would provide training, access to markets, as well as inputs and machinery, in exchange for profit sharing. However, the collapse of schemes following the departure of strategic partners indicates that the approach may not be sustainable and warrants further investigation. "The strategic partnership model as it stands now has not delivered and has not produced the desired outcome," the project team remarked.

Lack of business attitude and record-keeping

The farmers have no proper and detailed records of production costs, nor their seasonal water use or other input quantities. They are not aware if they have made a profit, and cannot demonstrate performance of the farm or irrigation scheme. "As long as farmers do not have an income/ expenditure attitude towards irrigated agricultural production, the level of production at the smallholder schemes will be low," noted the project team.

No prior arrangement of markets

The farmers cultivate the crops and only look for markets at the point of harvest. "This leads to produce fetching low prices, or failure to find a market in time, resulting in produce getting spoiled."

Vandalism and theft

Three of the schemes had experienced serious problems related to vandalism and theft of irrigation assets, which according to the project team could "be attributed to overall management problems and lack of accountability in leadership."

The project team proposed a number of interventions for improved performance of smallholder irrigation schemes in Limpopo province – and South Africa in general – including the adoption of the 'one block one household' approach and a comprehensive review of the strategic partnership model. They recommended that smallholder farmers be given training in basic business management, marketing and record-keeping, with a view to transforming them into entrepreneurs and business people. Likewise, easy and affordable irrigation scheduling methods should be introduced at the schemes, and training provided.

They noted too that there might be a need to investigate the operational costs, design and profitability of floppy irrigation systems – at the Mbahela irrigation scheme, for example, the

Lani van Vuuren

On many smallholder irrigation schemes, existing irrigation infrastructure is in dire need of maintenance.

farmers indicated that the average electricity bill of R13 000 per quarter for their system was unsustainable. Besides, a gradual conversion of existing large-scale sprinkler irrigation schemes to drip-irrigation farming would not only reduce water losses and wastage, but also allow the demarcation of farms into blocks for individual households.

Youth should be encouraged to get involved in the schemes and ultimately take over from ageing farmers. Promoting digital technologies could help make agriculture 'cool' in the eyes of young people, who tend to shun this industry the world over, said the project team. And vandalism experienced in some of the irrigation schemes should be addressed by the owners.

To solve problems related to the availability of agricultural machinery and equipment at the schemes, the project team recommended that mechanisation centres should be established at selected locations. "This will be cheaper as government intervention than purchasing individual farmers' tractors and implements," they noted.

They also pointed out, though, that the Agri-Parks concept launched by the Department of Rural Development and Land Reform in 2015 would provide the long-term answer to the majority of problems identified during the study. An Agri-Park is envisaged as a 'one-stop shop' for agro-production, processing, logistics, marketing, training and extension services, providing a networking platform as well as the necessary physical infrastructure. The guiding principles included that they would be farmer-controlled, based on a 70/30 equity principle, and would be supported by government for 10 years to ensure economic sustainability. The intention was to have an Agri-Park in each of South Africa's 44 municipal districts, but less than a dozen are currently up and running, despite the fact that government set aside R2.7 billion to roll out the programme.

It is interesting to compare the findings and recommendations of the WRC-funded project with those of an earlier survey, conducted in March-April 2016 and published by the International Water Management Institute (IWMI) the following year (van Koppen et al., 2017). A team from IWMI and the provincial (LDARD) and national (DAFF) agriculture departments surveyed 76 smallholder irrigation schemes in Limpopo, and found the overarching limitation to be the poor status of irrigation infrastructure, fencing and tractors. This was the case even in the 28 fully utilised schemes (the same number of schemes were not utilised at all during the 2015 winter irrigation season). In their report, the team recommended that further analysis should be done to unravel the multifaceted causes of infrastructure disrepair in order to overcome both the build-neglect-rebuild syndrome and the "vicious circle of lower productivity, lesser commitment of farmers, vandalism, and animal intrusion" at the irrigation schemes.

A wider review of "Challenges and opportunities for revitalising smallholder irrigation schemes in South Africa", published in ***WaterSA*** (Fanadzo and Ncube, 2018), focused on government policy and strategies to support smallholder farmers. The authors noted that the broad diversity of problems experienced countrywide implied that scheme-specific solutions should be identified and addressed in collaboration with the resident farmers. They felt, however, that the introduction of high-yielding, water-efficient and high-value crops should form part of the revitalisation intervention, and that more resources needed to be invested in training programmes for both farmers and extension officers.

"Research has shown that infrastructure development alone as a dominant part of revitalisation is bound to fail," note the authors. They point out that the WRC has produced a wealth of information on smallholder irrigation schemes, that the data was produced by expert researchers, and that the information is readily available. "For the government to repeat the same mistakes while recommendations for sustainability are available is therefore inconceivable," they conclude.

To downdload the WRC report, ***Factors influencing under-utilisation of smallholder Irrigation schemes and opportunities to improve the schemes' productivity in Limpopo province, South Africa*** **(Report No. TT 787/19)**, Visit: www.wrc.org.za.

Name of Irrigation Scheme	Location	District	Size (Ha)
Tshiombo-Mbahela	Thulamela	Vhembe	100
Mphaila	Makhado	Vhembe	71
Phetwane	Marble Hall	Sekhukhune	52
Kolokotela/ Krododilheuwel	Makhuduthamaga	Sekhukhune	240
Thabina	Greater Tzaneen	Mopani	228
Tours	Greater Tzaneen	Mopani	125

The smallholder irrigation schemes studied

CLIMATE CHANGE

Creating climate change resilient communities Part 2: Impact of climate resilience practices on rural livelihoods

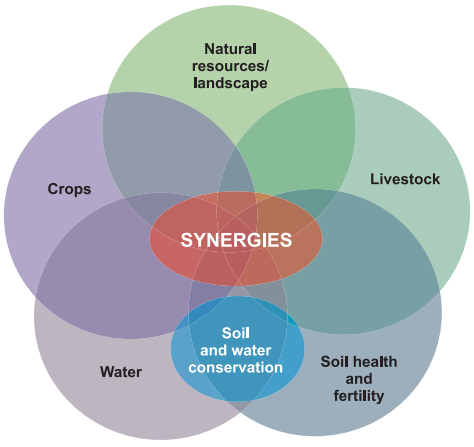
In this second article based on the Water Research Commission (WRC) funded project titled 'Collaborative knowledge creation and mediation strategies for the dissemination of water and soil conservation practices and climate smart agriculture in smallholder systems' we look at climate resilient agricultural practices and the impact of implementation of these practices on rural livelihoods. Article by Erna Kruger.

The project is exploring best practice options for climate resilient agriculture for smallholders and evaluating the impact of implementation of a range of these practices on the resilience of agriculture-based livelihoods. Alongside this, a decision support methodology and system has been designed to assist smallholders and the facilitators who support them to make informed and appropriate decisions about choices of a 'basket of options' for implementation at a local level.

Climate resilient agriculture (CRA) practices for smallholders

The approach is to work directly with smallholders in local contexts to improve practices and synergise across sectors. The emphasis is thus at farm/household level. Here, CRA aims to improve aspects of crop production, livestock and pasture management, natural resource management, as well as soil and water management as depicted in Figure 1.

Figure 1: Household level implementation of CSA integrates across sectors (adapted from Arslan, 2014)



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A database of 66 different practices falling into the categories mentioned in the figure above has been compiled, based on local suggestions and best bet options from experience and literature. A selection of the practices is shown in the table below. Farmers decide on practices to try out and implement depending on their own situations and preferences as well as suggestions made by the facilitation team.

Table 1: a summary of a selection of CRA practices considered and implemented by smallholder farmers

Gardening	Field cropping (Conservation Agriculture)	Livestock management
Intensive gardening techniques: including trench beds, mulching, liquid manure, mixed cropping, planting of nutritional herbs and multifunctional plants, fruit production, seed saving	Diversification of cropping: including legumes and cover crops (sunflower, millet, sunn hemp, black oats, fodder rye and fodder radish)	Fodder production and management for livestock
Soil and water conservation techniques: including swales, furrows and ridges, stone bunds, check dams	Intercropping and crop rotation; strip cropping options and spacing	Local feed production options
Tunnels; Shade cloth structures for microclimate control	No till planters	Chicken tractors
Rainwater harvesting; in field methods and storage options, small dams	Mulching, manure and organic options	Winter supplementation

For each practice, a 1-page summary has been put together, that can be presented to smallholders in the climate change adaptation workshops, for consideration by the smallholder farmers as a new idea or innovation to experiment with. This database provides a resource to farmers and facilitators to choose appropriate climate resilient agricultural practices for their area and their particular situation. It is one of the input parameters for the decision support process.

In addition, qualitative and quantitative indicators have been explored to physically assess the impact of these practices. These have included for example run-off, infiltration, water holding capacity in the soil profile, and water productivity as well as a number of soil- based parameters such as organic matter content, soil fertility and microbial activity.

As an example, a farmer level experimentation process consisting of production in trench beds, inside and outside of shade cloth tunnels was conducted. The control for this experiment was the farmer's 'normal' gardening practice – in this case raised beds.

Farmers kept careful records of the amount of water applied (irrigation) and their harvests (yields), alongside the research team who worked with local weather stations and soil moisture measurements to assess the water productivity of these practices.

The table below outlines the resultant water productivity calculation for this experiment. Both conventional water productivity calculations and a simpler format suggested by farmers that only uses their water applied were used.

Table 2: Water productivity for production of spinach inside and outside shade cloth tunnels for 2 smallholder farmers in KNV, Bergville

Bgvl June-Sept 2018	Simple scientific method (ET)			Farmers' method (Water applied)		
Name of famer	water use (m^3)	Total weight (kg)	WP (kg/m^3)	water use (m^3)	Total weight (kg)	WP (kg/m^3)
Phumelele Hlongwane trench bed inside tunnel	1,65	21,06	12,76	1,85	21,06	11,38
Phumelele Hlongwane; trench bed outside tunnel	0,83	5,32	6,45	1,75	5,32	3,04
Ntombakhe Zikode trench bed inside tunnel	1,65	17,71	10,73	2,37	17,71	7,47
Ntombakhe Zikode; trench bed outside tunnel	0,50	3,35	6,76	0,53	3,35	6,33

The control plots are not included here, as the two farmers realised quite early in the season that their normal production methods required too much water and opted to focus only on the trench beds. Water productivity is 60-100% higher for trench beds inside the tunnels when compared to trench beds outside the tunnel – using the more scientific approach that also takes into account evapotranspiration and leaching. This is a highly significant result, indicating the potential of micro-climate control in adaptation.

Water productivity calculate only from yields compared to water applied, shows a larger variation in results for the two participants. They both applied more water to their trench beds outside their tunnels, than inside; working on the assumption that the reduced growth

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for the crops outside the tunnel was due to water stress. This experimentation process assisted in their learning that plant stress also includes other factors such as temperature, wind and insect damage.

Participatory impact assessments

After a cycle of experimentation with the basket of CRA practices (one season/ 6 months), the process is reviewed and a participatory impact assessment process is conducted with the learning group members. It is important for community members themselves to develop the impact indicators/ criteria. Community members work in small groups to analyse for themselves the impact of the climate resilient agricultural practices they have been implementing.

Below is the result of a matrix ranking exercise conducted during this session. The research team were incredibly impressed with the depth of analysis participants undertook and with the impact indicators participants developed. It also indicates that smallholder farmers use integrated and systemic indicators to make their decisions and not just production and income data, commonly used in agriculture.

Table 3: Particiatory impact assessment of CRA practices by KZN participants, March 2019.

IMPACT INDICATORS PRACTICES	Soil; health and fertility	Money; income and savings	Productivity; acceptance of practice, saving in farming – equipment, labour	Knowledge; increased knowledge and ability to use	Food; how much produced and how healthy	Water; use and access	Social agency; Support, empowerment	Total
Conservation Agriculture	22	21	26	28	18	23	18	**156**
Savings	6	15	14	15	12	11	15	**88**
Livestock	19	11	18	7	5	12	11	**83**
Gardening	14	15	12	13	15	17	21	**107**
Crop rotation	16	12	13	12	12	15	10	**90**
Intercropping	12	13	15	12	11	11	9	**83**
Small businesses	11	17	15	10	20	11	9	**93**

Positive impact of CRA and associated practices in order of importance: Conservation Agriculture, gardening (tunnels, agroecology), small businesses (farmer centres, poultry), savings, livestock (integration – fodder, health)

The resilience snapshot put together from individual interviews for these same participants, gives a very strong indication of the benefit of CRA to the livelihoods of the rural poor. Climate change adaptation for these participants has resulted in increased availability of food, incomes and social agency and has provided hope for a more positive future for these participants.
Table 4: Resilience snapshot for KZN participants, March 2019.

A farmer level innovation approach to implementation of CRA practices in smallholder farming systems provides a powerful tool for community-based climate change adaptation and improvement of rural livelihoods.

Left to right: Spinach grown in a trench bed inside a tunnel, in a trench bed outside a tunnel and in a control bed (raised bed).

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AGRICULTURE AND POLLUTION

Toxic farm chemicals: Emerging threat to South Africa's surface waters

Scientists have raised concerns after finding high levels of toxic farm chemicals in local rivers and dams close to where genetically-modified (GM) maize crops are grown. Article by Tony Carnie.

All photographs courtesy NWU

The use of certain farm chemicals has risen dramatically among commercial farmers, partly due to the introduction of genetically modified maize strains that tolerate high doses of pesticides.

The first genetically modified (GM) maize crops were planted in South Africa more than 20 years ago amid industry promises of higher crop yields and a widespread reduction in toxic pesticide use.

Since then, however, the use of certain pesticides has risen dramatically among commercial farmers – partly due to the introduction of GM maize strains that tolerate high doses of pesticides and because of evolving natural resistance by several insect pests which has led to the use of larger volumes of pesticides or the use of more toxic chemical formulations.

Ground-breaking research published in the ***South African Journal of Science*** now suggests that potentially harmful levels of some of these herbicides are finding their way into country's already threatened aquatic environment. In a water-scarce country such as South Africa, chemical-contamination is of particular concern for rural families who still rely on untreated surface and groundwater resources.

Dr Suranie Horn and Prof Rialet Peters (Unit for Environmental Sciences and Management at North-West University, Potchefstroom) and Thomas Bøhn (Institute of Marine Research, Tromsø, Norway) say their study has highlighted the need for more regular and widespread monitoring of farm chemicals in the country's rivers, dams and other water courses.

Most significantly, the study found that concentrations of

the herbicide 2,4-D in tested South African surface waters exceeded the European guideline for drinking water, indicating a potential health risk for people using these water sources. This herbicide is classified as "possibly carcinogenic to humans" by the International Agency for Research on Cancer, a specialist agency of the World Health Organisation.

In a study entitled 'A first assessment of glyphosate, 2,4-D and Cry proteins in surface water of South Africa', Dr Horn and her research colleagues note that chemical compounds used in agriculture often end up in water sources and that their presence needs to be monitored. There are many such monitoring programmes worldwide, but none in South Africa for glyphosate, 2,4-D or Cry proteins, they noted.

The researchers say South Africa relies on agriculture to feed the majority of its people and is also ranked as the tenth largest maize producer in the world. As a result, herbicidal compounds used in this country should be designed to avoid toxic effects in non-target organisms.

"The first step is to monitor and determine whether herbicides and agricultural toxins used by farmers can be found in the environment. To our knowledge, this has not been done previously for Cry1Ab toxin, glyphosate and 2,4-D in South Africa, although these are dominant agrochemicals in modern South African agriculture. Thus, this report is the first investigation of the presence and concentrations of these substances in water sources in South Africa."

"From the results of this first survey conducted over a single maize growing season it is recommended that follow-up studies be undertaken which include more sampling locations across larger geographical regions in South Africa."

Dr Horn and her colleagues note that maize crops now cover about 2,8 million hectares, with the Free State, Mpumalanga and North West Provinces accounting for approximately 84% of total maize production in the country. Globally, there has been major advances in the agricultural sector over the past 40 years, which resulted in reduced crop losses and also reduced pesticide use.

This was partly due to the development of GM maize varieties into which several genes from other organisms, for example the Cry1Ab gene which naturally produces ***Bacillus thuringiensis*** (Bt) protein in the maize, was incorporated. Ingesting these proteins can be lethal for specific insect groups, including stem-boring lepidopteran species which is a maize crop pest.

While Cry proteins were often considered to be environmentally benign, with little or no effects on non-target organisms, recent studies have revealed increasing resistance by target insect pests. There had also been few studies on Cry proteins in water ecosystems and recent reports had indicated negative effects in mussels, some insects and other invertebrates like ***Daphnia magna.***

A separate genetic modification of maize had enabled such plants to be tolerant to the herbicide glyphosate (the active ingredient in Roundup®). These herbicide-tolerant crops, known as Roundup-ready maize, can be sprayed with glyphosate-based herbicides in larger quantities and during the entire period of the growing season without causing damage to the crops.

"If Roundup-ready maize is planted, the farmer may now spray more Roundup to kill the weeds and his maize will survive because they are resistant to Roundup,'" Dr Horn explains. "However, Bt-maize will need less insecticide to kill the lepidopteran insect that feeds on the maize itself because while

Dr Suranie Horn in the laboratory of the Unit for Environmental Sciences and Management at North-West University, Potchefstroom.

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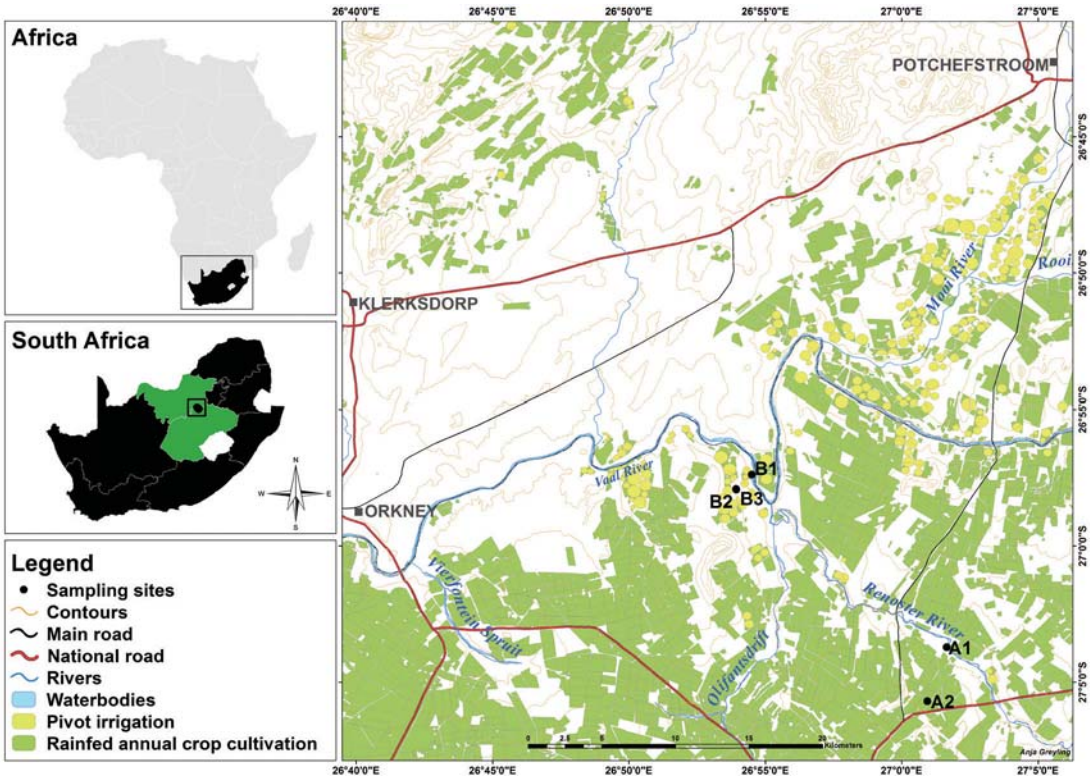

The water sampling sites where pesticides were collected near maize farms along the Free State and North West provincial border.

ingesting the maize plant the stem-borer also ingests the Cry protein that kills it. So, with Bt-maize, the farmer does not need to spray an insecticide."

Dr Horn's report notes that glyphosate was now the most widely used herbicide in the world although it has also been classified a probable human carcinogen by the International Agency for Research on Cancer, but not by the European Food Safety Authority. However, because several weed species had become resistant to this pesticide, some farmers were now using more toxic herbicides, such as 2,4-D.

Dr Horn and her colleagues report that South Africa is the biggest user of pesticides in sub-Saharan Africa, using more than 500 registered active chemical ingredients. "The use of herbicides on GM maize – of which 80% is the Roundup-ready version – has increased drastically over past years, and further increases are expected to occur in the next few years."

Generally, pesticides were developed to target specific pests and to be immobile. However, because of run-off, leaching and spray drift these compounds were spread into unintended sections of the environment, including water sources.

"These compounds generally occur at low concentrations, and it is assumed that they would not have detrimental effects on non-target organisms. However, exposure to low levels of pesticides poses a chronic risk to human health, including endocrine disruption, immune impacts, neurotoxicity, genotoxicity, carcinogenesis and mutagenicity."

The latest research by Dr Horn and colleagues involved sampling rivers and dams on two farms in the Free State, where Bt and Roundup-ready maize is grown and sprayed with Roundup and 2.4-D. Analysis showed that there were no detectable levels of Cry1Ab proteins in any of the water samples collected near the Free State farms – in contrast to tests in the United States corn belt, where these proteins were detected in 23% of 215 water samples.

With glyphosate, the levels were mostly below the limit of detection at most of the sites – also in contrast to tests in other countries such as Spain, where quantifiable levels were found in 41% of samples. However, almost all the water samples collected in the Free State contained measurable levels of 2,4-D (with a minimum of 0.72 µg/L and a maximum of 1.08 µg/L). The highest concentration was detected after spraying and decreased towards the end of the season.

These levels were higher than samples collected in Mexico, but lower than those collected in the United States.

While they were all below the maximum residue limit for pesticides in drinking water in both Canada and the USA – most of the Free State levels were an order of magnitude higher than the EU drinking water limit of 0.1 µg/L, and this could result in possible effects on human health.

For example, a Canadian study found a significantly increased risk of cancer (non-Hodgkin's disease) in men exposed to 2,4-D, while other studies reported that 2,4-D could reduce growth rates, induce reproductive problems, and produce changes in appearance or behaviour, or could cause death of non-target species, including plants, animals and microorganisms.

In contrast, other studies which examined the systemic toxicity, developmental neurotoxicity, developmental immunotoxicity, reproductive toxicity, endocrine modulation and thyroid effects in humans, had found that 2,4-D was unlikely to pose a significant health risk.

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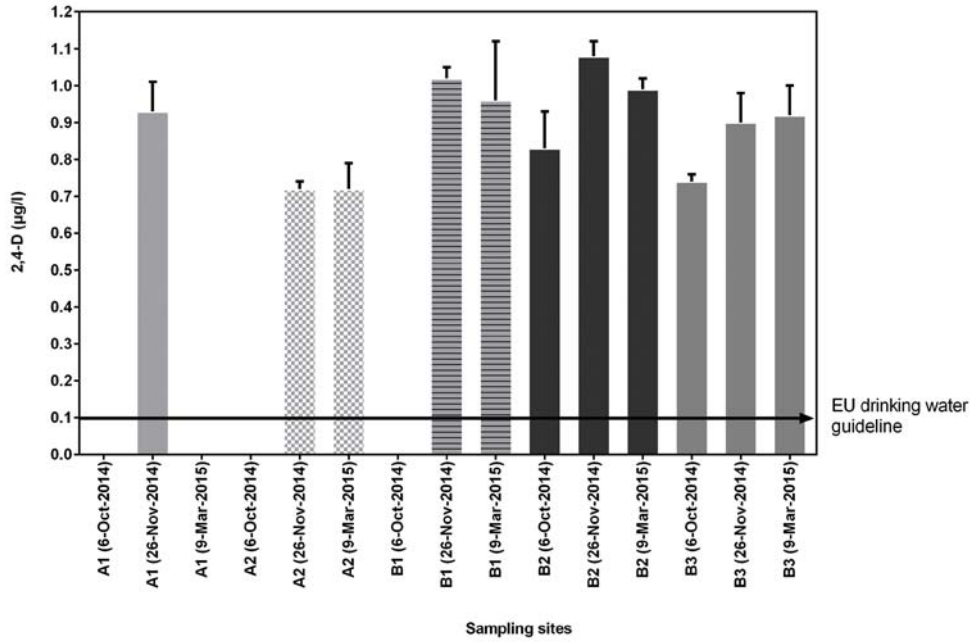

Concentrations of 2,4-D found across all sites, showing exceedances of the EU general drinking water guideline (0.1 µg/L).

A study by Dr Suranie Horn and Prof Rialet Peters from North-West University, Potchefstroom and Thomas Bøhn from the Institute of Marine Research in Norway has highlighted the need for more regular and widespread monitoring of farm chemicals in the country's rivers, dams and other water courses.

Nevertheless, Dr Horn and colleagues suggest that while the debate on the safety of herbicides continued, there may be unknown long-term effects on human health and the environment.

Overall, the researchers did not find Cry1Ab proteins at quantifiable levels and only one sample contained glyphosate. But 2,4-D was present at quantifiable levels in more than 70% of the samples and all of these concentrations exceeded the EU general guideline for drinking water.

"Recently, research has revealed adverse health effects of Cry1Ab, glyphosate and 2,4-D exposure to non-target organisms. These effects could also influence biodiversity; therefore, water sources should be monitored to ensure both healthy aquatic ecosystems as well as safe drinking water."

Asked to comment on why there appeared to have been little South African-based research on this subject previously, Dr Horn said: "A lot of research has been going on with GM maize and potential effects on non-target organisms, but it is not usually published in South African public domain journals. We could not find any publications with the levels of these three compounds for South Africa."

"Analysing for any of them is also expensive, whether using ELISA kits or via instrumental analysis. There is no laboratory that analyses for glyphosate or 2,4-D in this country, that we are aware of (at least not when we sampled in 2015). Cry analysis is also not done in SA on a wide scale. We are one of the only two labs that can do so for Cry1Ab specifically and we did it with ELISAs, not with an analytical instrument."

The researchers said they would like to analyse more rivers and water sources around South Africa, but are in need of further funding to continue this research.

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Water wheels

Harnessing nature's power

An ancient water mill in Spain.

Sure, we need water to drink, but have you thought about using water to create energy? Moving water has a lot of energy and all we need to do is to harness it.

One of the most successful means of harnessing water power is through the use of water wheels. A water wheel can basically be described as a device that uses flowing or falling water to create power by means of a set of paddles or buckets mounted around a wheel. The force of the water moves the paddles, and the consequent rotation of the wheel is transmitted to machinery via a shaft of the wheel. In this way the energy of the falling water is converted into useful forms of power.

Water wheels can either be horizontal or vertical (although the latter is most common). Early water wheels were manufactured from wood and other natural materials, such as bamboo. Later water wheels were manufactured from metal.

Water wheels require a nearby source of flowing or falling water. These sources could include streams or small rivers. Occasionally, special ponds (called mill ponds) would be built by damming a flowing stream. A special channel – called a mill race – would be created from the pond to the water wheel, so that flowing water could be accessed any time the water wheel was needed.

No-one knows exactly when or by whom the water wheel was originally invented. References to water wheels can be found in literature thousands of years old. All the ancient civilisations made use of water wheels – albeit of different designs, from the Chinese to the Greeks (and later the Romans), to ancient Middle Eastern civilisations. Water wheels were probably the first method of creating mechanical energy that replaced humans and animals. A mill could replace the power of ten to twenty people, producing on average two to three horsepower.

It was during the early Industrial Revolution that water wheels really came into their own. From monasteries to commercial factories, water wheels were used for everything from grinding flour, to hammering wrought iron, machining, ore crushing, crushing sugarcane, and pounding fibre for use in the

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manufacture of cloth. By the end of the eleventh century there were an estimated 5 600 mills in England alone!

In places such as Europe old water wheels can still be found, although they are now mostly used as tourist attractions.

The hydraulic turbine is a modern invention based on the same principles as the water wheel. It is a rotary engine that uses the flow of fluid, either gas or liquid, to turn a shaft that drives machinery. Hydraulic turbines are used in hydroelectric power stations. Flowing or falling water strikes a series of blades or buckets attached around a shaft. The shaft then rotates and the motion drives the rotor of an electric generator.

Water wheels in South Africa

Water wheels can also be found in South Africa. Perhaps the most famous are the water wheels found in the Northern Cape towns of Kakamas and Keimoes. Unlike Europe, these water wheels were not used so much in industry but rather to lift irrigation water from lower to higher irrigation fields.

The design of the South African water wheel is based on that of the noria, a water wheel which probably originated in Persia and that is basically a wheel fitted with buckets on the peripherals for lifting water (for this reason people used to refer to these water wheel as 'bakkiespompe').

This example of an overshot water wheel can be found in Derbyshire, England.

Lani van Vuuren

– A close up of the old restored water wheels at Kakamas.

The old water wheels at Kakamas contain small buckets that move water between irrigation canals.

Making a water wheel

Want to make your own water wheel? Watch the instructions here: https://www.wikihow.com/Make-a-Water-Wheel

Sources

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BUCHUBERG – THE 'FORGOTTEN' DAM OF THE ORANGE RIVER

All photographs by Lani van Vuuren

The Buchuberg Dam on the Orange River.

The old crane used to open the dam's 68 sluices.

The Buchuberg Dam – so named for the Buchu plant that occurred in the area – was the first dam of significant size to be constructed in the lower Orange River. While decision-makers mulled over the possibility of an irrigation scheme in the area from as early as 1872 it was the Great Depression and concomitant drought of the 1930s that gave impetus to the scheme. In 1929, it was decided to build the Buchuberg Dam and associated infrastructure as a job-creation scheme. The dam was constructed almost entirely by hand, and around 350 men worked on the dam site. Initially, everything, from labourers to

The main irrigation canal.

equipment, sluices and even the stone crusher was transported piece by piece by donkey cart from the nearest train station at Draghoender, more than 60 km away. The donkeys were later replaced by trucks, rented from richer farmers in the region.
By 1932, construction of the dam had advanced enough for water to flow into the canal for the first time. The dam wall was constructed to a final height of 10,7 m and is 622 m long. The dam was initially equipped with 68 sluices designed to allow sediment to pass through the structure. The main irrigation canal is 121 km long, and was completed in 1934. Although the dam had an initial storage capacity of 40 million m^3, this has been halved through the years through sedimentation. The sediment sluices have been closed permanently and the structure is now effectively a concrete weir, which supplies water into the canal on the left bank.

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DEEPLY ROOTED IN SOUTH AFRICA WATER SOCIETY

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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.

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